ECONOMY TESTS OF 40. H. P. AUTOMOBILE ENGINE

BY

M. F. LAWRENCE

W. C. DUNN

ARMOUR INSTITUTE OF TECHNOLOGY

1912

625.6
L 41

[illegible]
[illegible]
UNIVER[illegible] [illegible]RARIES

FOR USE IN LIBRARY ONLY

AT 260
Lawrence, M. F.
Economy test of 40 H. P.
automobile engine including

ECONOMY TESTS

OF

40 H. P. AUTOMOBILE ENGINE

INCLUDING

CONSTRUCTION AND OPERATION

OF

MANOGRAPH

ILLINOIS INSTITUTE OF TECHNOLOGY
PAUL V. GALVIN LIBRARY
35 WEST 33RD STREET
CHICAGO, IL 60616

A THESIS

PRESENTED BY

MEREDITH F. LAWRENCE

AND

WILL C. DUNN

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

MECHANICAL ENGINEERING

H. M. Raymond
Dean of Eng. Studies

L. C. Monin
Dean of Cult. Studies

Rec'd 5/29/30
H. F. Gebhardt

625.6
L41

Index

Introduction--------------------------------pg. 1
Outline of Tests----------------------------pg. 2
Observations and Conclusions----------------pg. 4
Description of Engine-----------------------pg. 6
Description of Manograph--------------------pg.10
Description of Apparatus--------------------pg.13
Determination of Heat Value of Fuel---------pg.21
Test Number One-----------------------------pg.25
  Conditions--------------------------------pg.26
  Calculations------------------------------pg.26
  Log Sheets--------------------------------pg.29 & 30
  Cards-------------------------------------pg. 31 & 32
  Discussion--------------------------------pg. 33
Test Number Two-----------------------------pg. 36
  Conditions--------------------------------pg. 37
  Calculations------------------------------pg. 37
  Log Sheets--------------------------------pg. 39 & 40
  Cards-------------------------------------pg. 41 & 42
  Discussion--------------------------------pg. 43
Test Number Three---------------------------pg. 45
  Conditions--------------------------------pg. 46
  Calculations------------------------------pg. 46
  Log Sheets--------------------------------pg. 48 & 49
  Cards-------------------------------------pg. 50 & 51
  Discussion--------------------------------pg. 52
Test Number Four----------------------------pg. 53
  Conditions--------------------------------pg. 54
  Calculations------------------------------pg. 54

23494

  - Log Sheets---pg 56 & 57
  - Cards---pg. 58 & 59
  - Discussion---pg. 61
- Test Number Five---pg. 64
  - Conditions---pg. 65
  - Calculations---pg. 65
  - Log Sheets---pg. 67 & 68
  - Cards---pg. 69 & 70
  - Discussion---pg. 71
- Test Number Six---pg. 74
  - Conditions---pg. 75
  - Calculations---pg. 75
  - Log Sheets---pg. 78 & 79
  - Cards---pg. 80
  - Discussion---pg. 80
- Test Number Seven---pg. 83
  - Conditions---pg. 84
  - Calculations---pg. 84
  - Log Sheets---pg. 86 & 87
  - Cards---pg. 88
  - Discussion---pg. 89
- Test Number Eight---pg. 92
  - Conditions---pg. 93
  - Calculations---pg. 94
  - Log Sheets---pg. 96 & 97
  - Cards---pg. 98
  - Discussion---pg. 98
- Curves---pg. 99a

Discussion of Curves----------------------------pg.100
Valve Timing Diagram----------------------------pg. 102
Manograph Disc Calibrations---------------------pg. 103

List of Illustrations.

Cut of Engine----- Cut No.1--------------------pg. 8
Cut of Engine----- Cut No. 2-------------------pg. 8
Cut of Engine----- Cut No. 3-------------------pg. 8
Cut of Carbureter------Cut No.4----------------pg. 9
Diagram of Manograph--Fig.1--------------------pg.12
Diagram of Manograph--Fig. 2-------------------pg.12
Sketch of Apparatus---Fig.3--------------------pg.15
Photo of Apparatus----Photo 1------------------pg. 19
Photo of Apparatus----Photo 2------------------pg. 19
Photo of Apparatus----Photo 3------------------pg. 20

Introduction.

In carrying through these tests, we, as the experimenters, had two things in mind. First, we wished to get definite information as to the fuel economy and the efficiency of a typical automobile gasoline engine, as well as the variation in horse power and torque with the speed of rotation. Second, we wished to investigate conditions in the cylinders of this engine during these experiments by means of indicator cards.

To accomplish the first, we proposed to run a series of tests upon the engine, determining the desired quantities for different loads, and from these tests, to plot curves showing their variations with the loads.

To make the second possible, it was necessary to provide some means for taking the indicator cards other than the ordinary gas-engine indicator on account of the high speed of the engine. For this purpose we used a manograph, which we found necessary to alter to meet the conditions. The

adapting of the manograph to meet these conditions required considerable thought and work and was included as a part of the thesis.

Outline of Tests.

In regardto the first part of the thesis, namely, the efficiency and economy tests, we decided to conduct eight tests, each test to supply the necessary data for the establishing of a point on each curve. To this end eight tests were run with the following readings recorded.

1. Gross brake load in lbs.
2. Speed of rotation in R.P.M.
3. Initial and final weights of gasoline in the feed tank, lbs.
4. Weight of cooling water used, lbs.
5. Inlet cooling water temperature, ° F
6. Outlet cooling water temperature, ° F
7. Time; hours, minutes and seconds.

The following constant quantities were also recorded.

1. Tare weight of brake arm and stand
2. Length of brake arm.
3. Room temperature
4. Weather conditions, i.e., barometer, cloudiness, temperature, and wind direction and velocity.

From this date the following quantities were calculated.

1. Horse Power
2. Gasoline Consumption Rate.
3. Torque
4. Heat Consumption Rate
5. Per cent Heat Lost to Cooling
6. Percent Heat Lost to Radiation, Exhaust, etc.
7. Thermal Efficiency.

Incidental to these tests, the valve timing diagrams for the different cylinders were drawn and the heat value of the gasoline was determined from the Mahler Bomb.

In connection with each test, manograph cards were taken, and the best of these selected for each test. These representative cards were discussed individually, and the relative pressures scaled and recorded on those cards which we selected as average

cards.

Observations and Conclusions from the Tests.

From the results from the first part of the tests, we came to the following general conclusions.

1. That the fuel economy of this engine, starting with a light load, increases with the increase of load until a load of approximately 35 H.P. is reached, when further increase of load produces a decrease in economy of fuel.
2. That the best economy of fuel for this engine under the existing conditions is .593 lbs. of gasoline per B.H.P. per hour.
3. That the horse power of the engine increases with the speed, tending to come to a maximum at a certain definite speed.
4. That the torque rises with the speed until a maximum is reached and then drops off with a further increase of speed.
5. That the highest thermal efficiency of this engine , under the existing conditions, is 22.92 per cent.

From the second part of the experiment , the following conclusions are drawn.

1. That an optical indicator is the only satisfactory means of determining the conditions within the cylinders of a high speed gasoline engine, yet produced.

2. That a manograph can be made to give satisfactory results in actual practice if constructed upon the proper lines.

3. That the arc light is the most satisfactory source of illumination for the manograph.

4. That the cycle of events inside a high speed gasoline engine cylinder is remarkably regular and uniform.

5. That the manograph, while not furnishing accurate record of the pressures, is very useful and reliable in recording the actual performance of the cycle and in pointing any defects in the cycle.

6. That with a properly constructed manograph, long and tedious developing of the card photographs is not necessary, four minutes being sufficient with the proper appliancės.

Description of the Engine.

The motor which was the subject of these tests was a "Model R.A.Rutenber" motor, manufactured by the Western Motor Co. of Marion, Ind. It is a four cylinder, four cycle, "L" head motor of the poppet valve type, having a bore of 4-1/2 inches and a stroke of 5 inches; total piston displacement 318 cu.in.

It is rated 32.4 A.L.A.M., at 1000 R.P.M. and is called a 35-40 horse power motor. The inlet and exhaust valves are the same size, 2 inches dia. with a valve opening dia. of 1-3/4 inches. It carries a fly wheel of 16-5/8 inches dia. and 4-7/8 inch face and weighs complete 450 lbs.

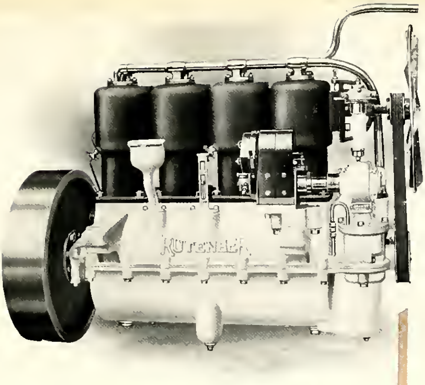
The oiling is by a positive gear pump and a constant crank case level splash system. An indicator integral with the upper crank case and consisting of a ball float with an indicating knob sliding up and down in a glass sight tube, shows the level of the oil in the pan.

The engine is water-c oled, a small gear pump run from the crankshaft supplying the water under

pressure to the cylinder water jackets.

Cut No. 1 shows the magneto side of the engine with the magneto, the distributor, the oil strainer, and the oil level indicator plainly evident. Cut No. 2 gives a view of the valve side of the engine, with the inlet and exhaust manifolds shown, also the water pump and connections. The carbureter is fastened to the flange shown on the inlet manifold. Cut No. 3 shows a partial cross section of the valve side of the engine. From this view an idea of the construction of the valves, pistons and rods, and the cranks can be obtained.

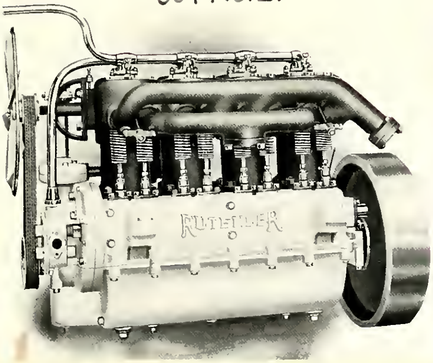
The carbureter used was a "Schebler Model E" made by the Wheeler and Schebler Co., Indianapolis, Ind. Cut No. 5 shows a detailed cross-section of this carbureter with the various parts named.



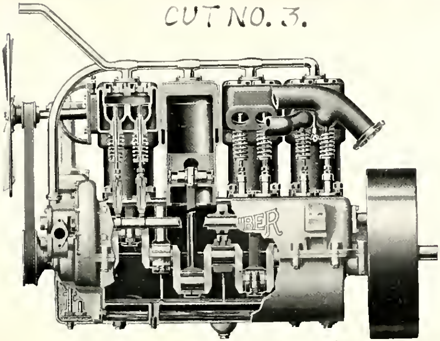
Models W-RA and U Magneto Side

CUT NO. 1.

CUT NO. 2.

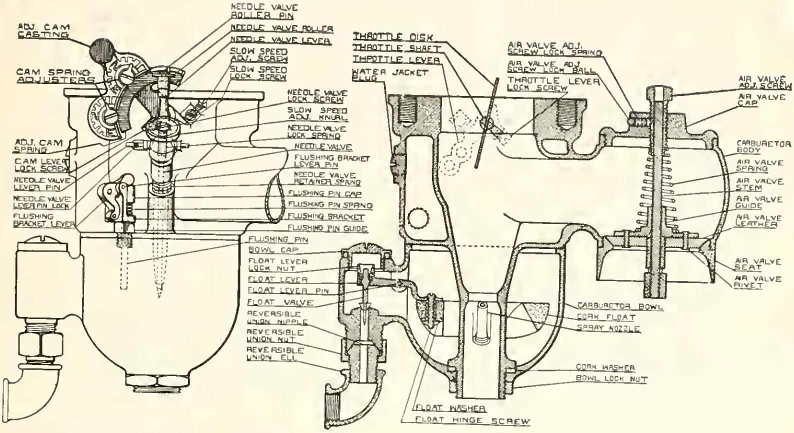


CUT NO. 3.



Models W RA and U Cross Section Valve Side

CUT NO. 4.


ADJ. CAM CASTING
CAM SPRING ADJUSTERS
ADJ. CAM SPRING
CAM LEVER LOCK SCREW
NEEDLE VALVE LEVER PIN
NEEDLE VALVE LEVER PIN LOCK
FLUSHING BRACKET LEVER
NEEDLE VALVE ROLLER PIN
NEEDLE VALVE ROLLER
NEEDLE VALVE LEVER
SLOW SPEED ADJ. SCREW
SLOW SPEED LOCK SCREW
NEEDLE VALVE LOCK SCREW
SLOW SPEED ADJ. KNURL
NEEDLE VALVE LOCK SPRING
NEEDLE VALVE
FLUSHING BRACKET LEVER PIN
NEEDLE VALVE RETAINER SPRING
FLUSHING PIN CAP
FLUSHING PIN SPRING
FLUSHING BRACKET
FLUSHING PIN GUIDE
FLUSHING PIN
BOWL CAP
FLOAT LEVER LOCK NUT
FLOAT LEVER
FLOAT LEVER PIN
FLOAT VALVE
REVERSIBLE UNION NIPPLE
REVERSIBLE UNION NUT
REVERSIBLE UNION ELL
THROTTLE DISK
THROTTLE SHAFT
THROTTLE LEVER
WATER JACKET PLUG
AIR VALVE ADJ. SCREW LOCK SPRING
AIR VALVE ADJ. SCREW LOCK BALL
THROTTLE LEVER LOCK SCREW
AIR VALVE ADJ. SCREW
AIR VALVE CAP
CARBURETOR BODY
AIR VALVE SPRING
AIR VALVE STEM
AIR VALVE GUIDE
AIR VALVE LEATHER
AIR VALVE SEAT
AIR VALVE RIVET
CARBURETOR BOWL
CORK FLOAT
SPRAY NOZZLE
CORK WASHER
BOWL LOCK NUT
FLOAT WASHER
FLOAT HINGE SCREW

Description of the Manograph.

The manograph was made by J. Carpentier in France. It consists mainly of three parts; first, the source of light, which we supplied by an arc light; second, the mirror with its mechanism; third, the box with its prism and lenses to conduct the light to the mirror, its glass screen, and its tripod stand.

As a source of light we tried, first, a tungsten filiament electric light, with the apparatus arranged as in Fig. 1. Light from the tungsten filament passed through the pinhole, P, and fell upon lens L_1, which was placed at its focal distance from the pinhole. The light made parallel by lens L_1 passed to lens L_2, which had a focal distance equal to the total path from its center to the screen, by way of the prism, K, and the mirror M. When this arrangement was tried, it was found that mirror M was concave and a flat mirror was substituted. A spot of light was obtained but it was large and hazy and would not affect the fastest films we could buy. We therefore decided to try an arc light and after some experimenting arrived at the arrangement in Fig. 2. Light from the crater of the

arc, which was constructed with the carbons at 90° to each other, falls upon lens L_1, and L_1 being at its focal distance from the arc, the light is made into a broad parallel beam. The pin-hole, P, allows a single element of this beamto pass into the box and fall upon the prism K which deflects it to the concave mirror, M, from which it passes to the screen. With this arrangement we got a small, very intense dot of light with only a very slight haze which did not affect the cards to any extent. The arc, being, roughly, 200 times as intense as the tungsten filament, gave us correspondingly brighter spot of light. With this spot, we found that only one cycle on a card was distinctly visible and a development of but four minutes gave satisfactory results.

As regards the second part of the instrument, the mirror and its mechanism, the mirror is mounted upon three points. One of these points is stationary, one moves in accordance with the pressures, and the third moves in relation to the movement of the piston in the cylinder. The second point, the one actuated by the pressures in the cylinder, is pushed in or out by a thin circular metallic disc, which is exposed to the

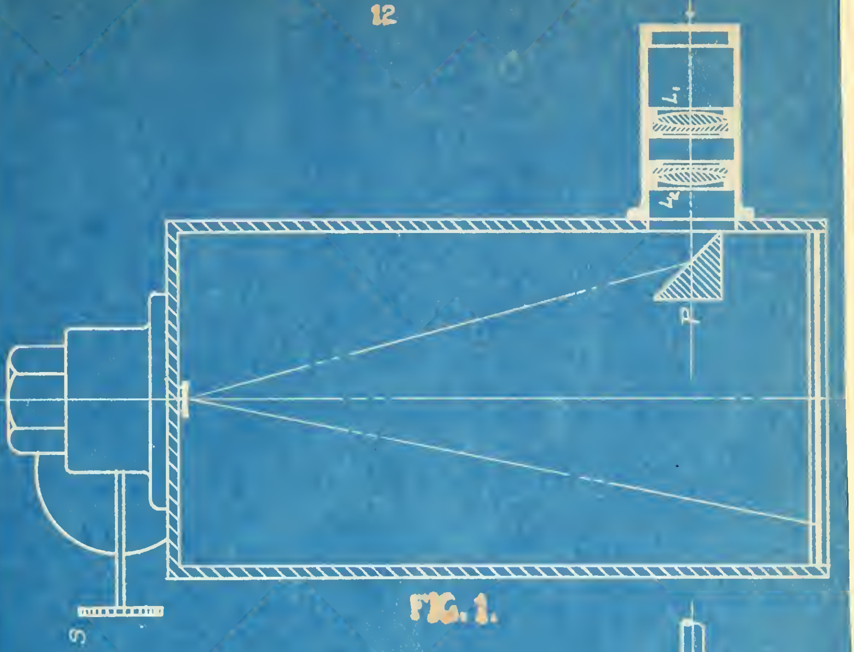


FIG. 1.

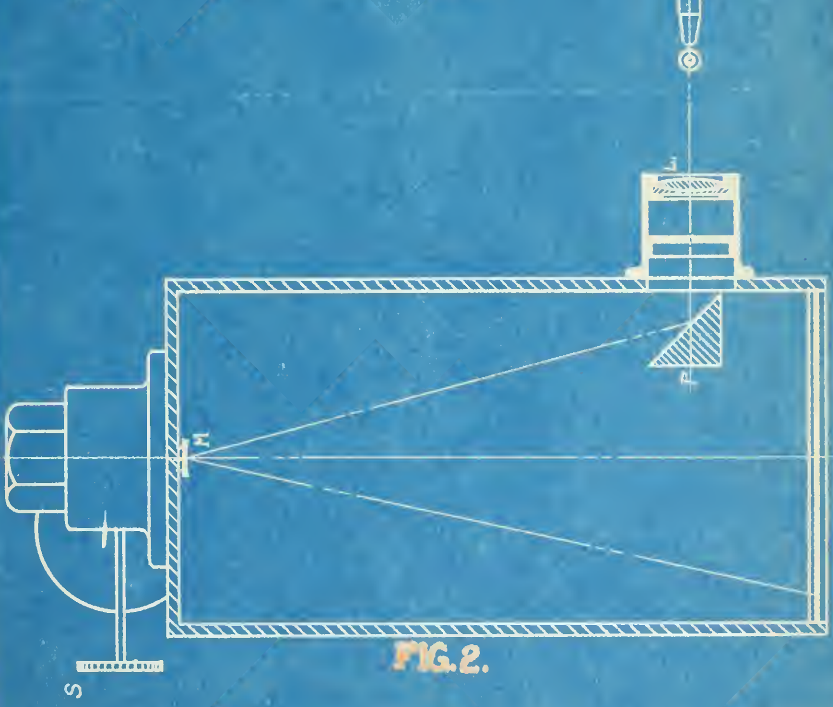


FIG. 2.

pressure of the gases through a tube leading to the cylinder, and deflects accordingly. This disc is what might be called the "heart" of the instrument. It is calibrated for different pressured and corresponds to the spring in an indicator.

The third point, the one which moves in relation to the piston of the engine, is connected with the crankshaft of the engine by a flexible shaft and it is put in step with the piston by means of the screw, S, which changes the angularity until the piston and mirror are in step, the proper relation being found by watching the card while screw S is being adjusted.

The manograph box is made of wood and the prism, K, is mounted so that it may be turned about a vertical axis so that the beam of light can be centered upon mirror, M. The glass screen slides in grooves in the end of the box and may be replaced by the plate holder. The tripod screws on to the bottom of the box and is built solidly to stand vibration.

Description of the Apparatus.

The apparatus consisted of the following.

1. Brake, with its stands and scales.
2. Gasoline tank with its stand and scales.

3. Water tanks with their scales
5. Thermometers, one for inlet cooling water, and one for outlet cooling water.
6. Revolution counter.
7. Watch

The brake was an Alden Dynamometer, its shaft connected to the engine shaft by a coupling. The brake consists of a cast iron disc, keyed to the shaft, and running between two copper discs with a film of oil over the rubbing surfaces. The discs are mounted in a casing and are exposed to water pressure which presses them against the revolving cast iron disc, producing the necessary friction. Since the copper discs are rigidly connected to the casing, the casing tends to revolve upon the application of water pressure, and the brake arm being fastened to the casing can be supported on the scales in the same manner as a Prony brake and the turning effort measured. The compartment between the copper discs, in which the cast iron disc revolves, is closed off from the inside of the casing which holds the water, and contains a bath of oil. This

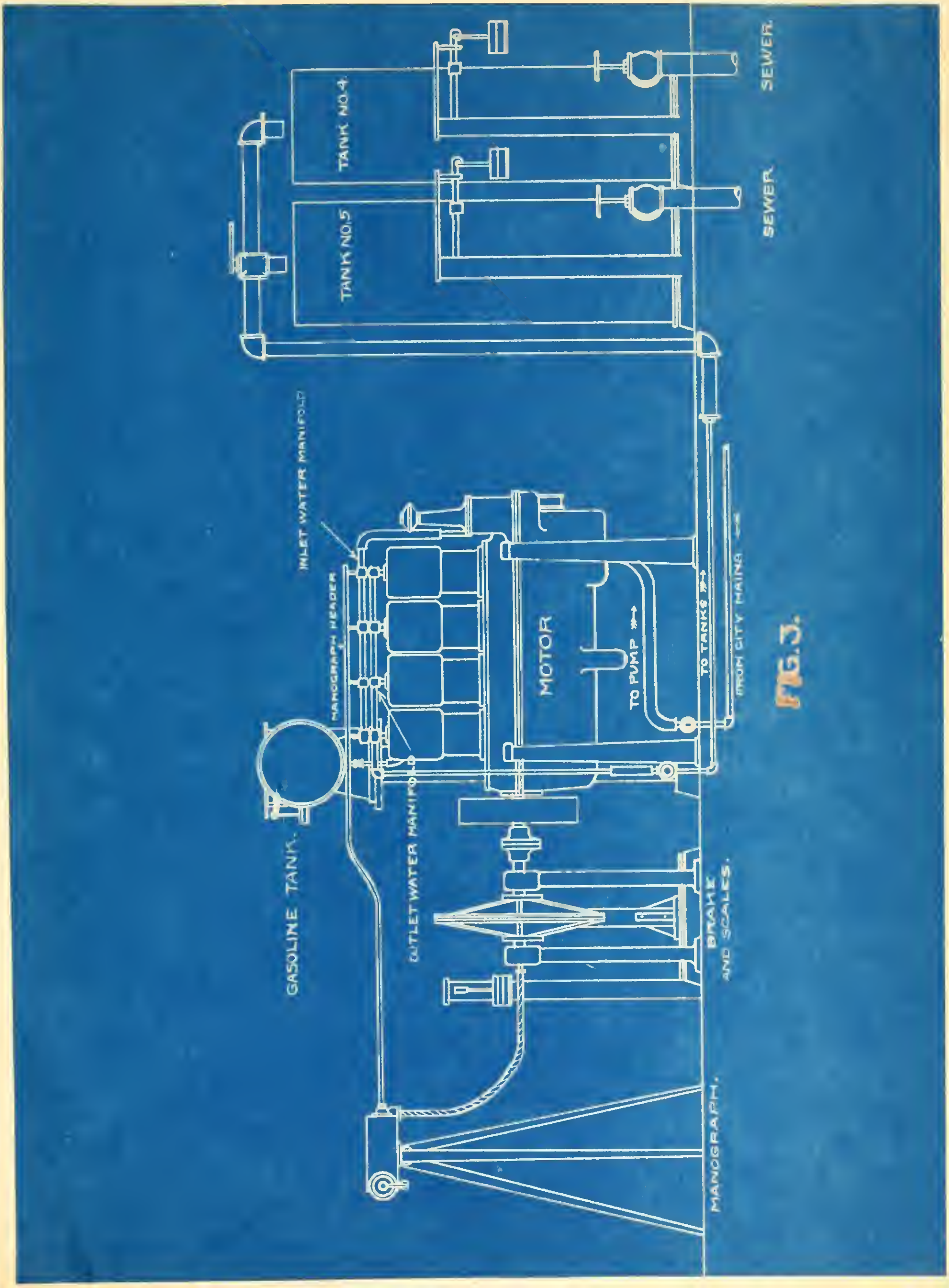

GASOLINE TANK.
OUTLET WATER MANIFOLD
MANOGRAPH HEADER
INLET WATER MANIFOLD
MOTOR
TO PUMP
TO TANKS
FROM CITY MAINS
TANK NO.5
TANK NO.4
SEWER
SEWER
BRAKE AND SCALES.
MANOGRAPH.

FIG. 3.

brake, in connection with the constant pressure from a standpipe in the building, worked very satisfactorily. A Fairbanks scales was used with the brake and read to tenths of a pound.

The gasoline tank held about five gallons of fuel and was supported on a pair of small, 100 lbs. Fairbanks scales, reading to hundredths of a pound, resting upon a stand above the carbureter level.

Cooling water was taken diredtly from the city mains and after passing through the engine, flowed to two tanks shown in fig. 3. These tanks each had a capacity of 1500 lbs. of water and were placed upon Fairbanks scales reading to tenths of a lb. They were provided with suitable valves and piping to discharge into the sewer.

The thermometers were numbered I and II, number I going in the inlet cooling water, and number II in the outlet cooling water. These thermometers read in degrees F and were carefully calibrated and found correct.

Fig. 3 shows, diagrammatically, the arrangement of the apparatus, and Photos 1, 2, and 3 show clearly the apparatus as it looked. Photo 1 shows

the apparatus viewed just to the right of the front of the engine. Photo 2 shows a view from the left of the front of the engine, and Photo 3 shows a rear view of the apparatus.

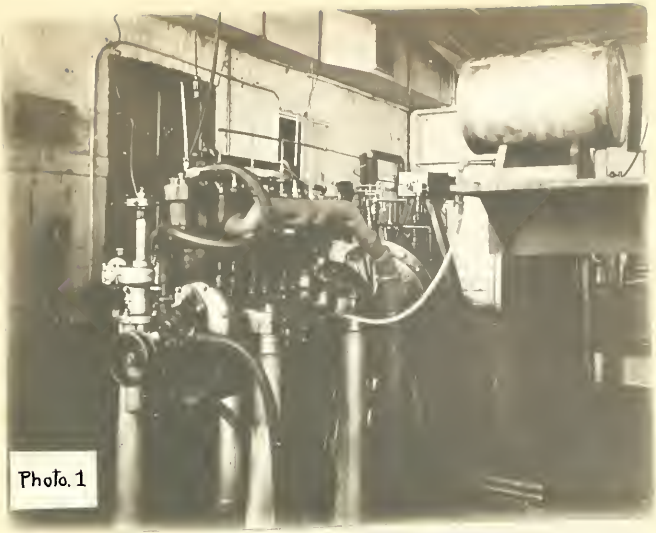


Photo. 1

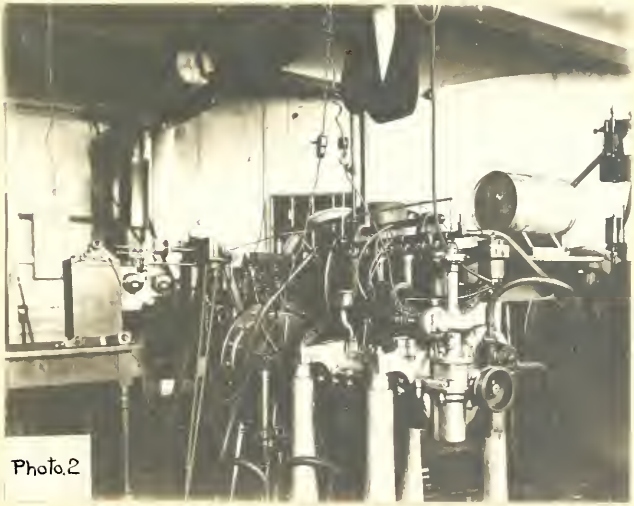


Photo. 2

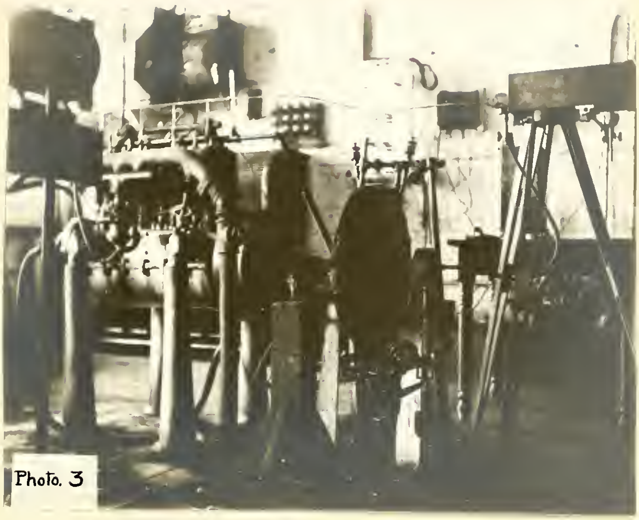


Photo. 3

Determination of the Heat Value of the Fuel.

Index.

Determination of Specific Gravity of
    Gasoline............................Page 22
B.T. U. per lb. from Empirical formula.. 22
B. T. U. per lb. from Mahler Bomb Test.... 22
    Weights and Volumes.................. 22
    Heat of Capsule...................... 22
    Radiation Rate before Explosion...... 23
    Heat of Explosion of Bomb............ 23
    Radiation Rate after Explosion....... 23
    Radiation Correction................. 24
    Heat Developed by Combustion......... 24
    High Heating Value of Gasoline....... 24
    Low Heating Value of Gasoline........ 24

Determination of the Heat Value of the Fuel

Specific Gravity of Gasoline;

Degrees Baume 64.9

Temperature correction 1.4

Corrected value 63.5°

Corresponding Specific Gravity 0.72345 B.T.U. per lb. from Empirical Formula;

B.T.U. (high value) = 18650 + 40(B°-10) where B Baume degrees.

B.T.U. = 18650+40(63.5-10)

= 20,790 B.T.U. per lb.

B.T.U. per lb. from Mahler Bomb Test;

Weight of capsule and wire	.0964 gm.
Weight of capsule and gasoline	.3000 gm.
Weight of gasoline sample	.2036 gm.
Volume of water in calorimeter	2200 c.c.
Water equivalent of bomb	512 c.c.
Total water volume	2712 c.c.

Heat value of capsule 4600 calories per gm.

Weight of one capsule .06793 gm.

Heat value of capsule, net, = .06793 x 4600=312 cal.

Radiation Rate Before Explosion.

(readings every 1/2 min. for 5 mins.)

Time	Temp.
3:05:00	3.66
3:05:30	3.67
3:06:00	3.67
3:06:30	3.68
3:07:00	3.68
3:07:30	3.68
3:08:00	3.68
3:08:30	3.68
3:09:00	3.68
3:09:30	3.68

3.68° - 3.66°= .02°

$\frac{.02}{5}$ = .004° C per min.

Heat of Explosion of Bomb

Time	Temp.
3:10:00	3.680
3:10:30	3.800
3:11:00	4.300
3:11:30	4.570
3:12:00	4.610
3:12:30	4.618
3:13:00	4.620
3:13:30	4.621
3:14:00	4.621
3:14:30	4.621

4.621° - 3.680° = .941 C° Rise

Radiation Rate after Explosion.

Time.	Temp.
3:15:00	4.621
3:15:30	4.615
3:16:00	4.610
3:16:30	4.610
3:17:00	4.609
3:17:30	4.608
3:18:00	4.605
3:18:30	4.600
3:19:00	4.598
3:19:30	4.592

4.621° - 4.592° = .029°

$\frac{.029}{5}$ = .0058° C per min.

Correction for Radiation.

Temperature rise .941° C

Time of temp. rise 4 min.

Radiation rate .0058° per min.

True rise in Temperature = .941 + 4 x .0058 = .9642° C

Heat developed by Combustion:

.9642 x 2712 = 2612 Calories

Heat value of capsule = 312 calories

Heat value of gasoline = 2300 calories; heat value of sample.

Heat value of sample per gm.:

$$\frac{2300}{.2036} = 11,297 \text{ calories per gm.}$$

Heat value of sample in B.T.U. per lb.

$$\text{B.T.U.} = \frac{11,297 \times 453.59}{253} = 20,200 \text{ B.T.U. per lb.}$$

Since with the combustion of 1 lb. of fuel, approximately 1.4 lbs. of water is formed, and since this necessitates the expenditure of 1500 B.T.U. the low value of the gasoline is,

20,200 - 1500 = 18,700 B.T.U. per lb.

Test Number One.

Index

Condition of Test----------------------------pg. 26
    Load------------------------------------pg. 26
    Speed-----------------------------------pg. 26
    Atmospheric-----------------------------pg. 26
Running Log of Test-------------------------pg. 29
Calculations--------------------------------pg. 26
Finished Log of Test------------------------pg. 30
Cards---------------------------------------pg. 31 and 32
Discussion of Test--------------------------pg. 33
    Test------------------------------------pg. 33
    Cards-----------------------------------pg. 33

Test Number One was performed with the brake set at the lowest load, namely 25 lbs. net on the scales, making a gross scale reading of 34 lbs., nine pounds being the tare weight of brake arm and stand.

The speed was held as near 615 revolutions per minute as possible, the engine pulling evenly and steadily at this speed with the specified load.

The day was clear, 10/10 ths. sunshine, with an average temperature of 28° F, and an east wind, average velocity 9 miles per hour. The barometer average was 29.25 and the room temperature 56° F.

Calculations of Test Number One.

(Refer Log Sheets, pgs 29 and 30)

Horse Power:

$$B.H.P. = \frac{2\pi rnw}{33,000}$$

r = brake arm = 1.864 feet

n = revolutions per minute = 614.2 (average)

w = net brake load = 25 lbs.

$$B.H.P. = \frac{2 \times 3.1416 \times 1.864 \times 25 \times 614.2}{33,000} = 5.45$$

Gasoline Consumption;

$$\text{lbs. per B.H.P. per hr.} = \frac{4.8}{5.45} = .8805$$

Heat consumption:

B.T.U. per B.H.P. per hr. $= \frac{4.8 \times 18,700}{5.45} = 16,470$ B.T.U. per B.H.P. per hr.

Total B.T.U. used:

$4.8 \times 18,700 = 89,750$ B.T.U.

B.T.U. given up to cooling:

$813(92.61-35.76) = 46,250$ B.T.U.

Percent of Total Heat to Cooling:

$\frac{46,250}{89,750} = .515$ or 51.5 %

Heat equivalent of B.H.P.

$5.45 \times 2545 = 13,880$ B.T.U.

Heat Lost to Radiation, Exhaust, etc.

$89,750 - (46,250 + 13,880) = 29,620$ B.T.U.

Per cent of Total Heat to Radiation, Exhaust, etc.

$\frac{29,620}{89,750} = .330$ or 33.0 %

Thermal Efficiency; (Per B.H.P.)

$\frac{13,880}{89,750} = .1550$ or 15.50 %

Theoretical Thermal Efficiency:

$$E = 1 - \left(\frac{V_b}{V_a}\right)^{n-1}$$

V_a = total vol. cylinder = 103.9 cu. in

V_b = vol. clearance space = 24.4 cu.in.

$n = 1,406$

$$E = 1 - \left(\frac{24.4}{103.9}\right)^{1.406-1} = .4445 \text{ or } 44.45\ \%$$

Note: Since the actual thermal efficiency is based upon B.H.P., no efficiency ratio can be calculated from it in connection with the theoretical thermal efficiency, and this last serves as a comparison only.

MECHANICAL ENGINEERING LABORATORY
ARMOUR INSTITUTE OF TECHNOLOGY

Test of Rutenber Automobile *Gas Engine*
Type 4 cylinder - 4 cycle
Size 4-1/2 x 5 "
Fuel Used Gasoline

Brake ~~Circumference~~, ft. arm 1.864 ft.
Dead Weight of Arm, lbs.
On Scales, lbs. 9
Total, lbs. 9

LOG OF TEST: No. 1 Barometer 29.25 Date 3/23/12

						TEMPERATURE—DEGREES F					PRESSURE		WEIGHTS			HORSE POW'R	
TIME	REVOLUTION COUNTER	EXPLOSIONS PER MINUTE	REVOLUTIONS PER MINUTE	GAS METER	CUBIC FEET GAS PER HR.	Entering Jacket Water	Issuing Jacket Water	Gas at Meter	Room	Exhaust	Gas at Meter, In. Mer.	At Eng., In. Water	Jacket Water	Scale Reading	Brake Load, Net	B. H. P.	I. H. P.
10:42			572		35.05	36	90.0		Tank #4 - Tare				519	34	25		
10:47			637			36	93.5							34	25		
10:52			605			36	94.0							34	25		
10:57			628			36	92.0							34	25		
11:02			618			36	91.6							34	25		
11:07			616			36	92.0							34	25		
11:12			601			36	91.0							34	25		
11:17			608			36	91.0							34	25		
11:22			627			35	92.0							34	25		
11:27			624			35	92.0							34	25		
11:32			610			35	91.5							34	25		
11:37			625			36	91.5							34	25		
11:42			615		30.25	36	92.0		Tank #4 Final				1332	34	25		
			No. lbs. Gasoline				4.8		No. lbs. water used					813			
Averages			614.2		4.8	35.76	92.61						813	34	25	5.45	

REMARKS

M.F.Lawrence, W. C. Dunn Observer.

MECHANICAL ENGINEERING LABORATORY
ARMOUR INSTITUTE OF TECHNOLOGY

Test of Rutenber Automobile *Gas Engine* *Date* 3-23-12

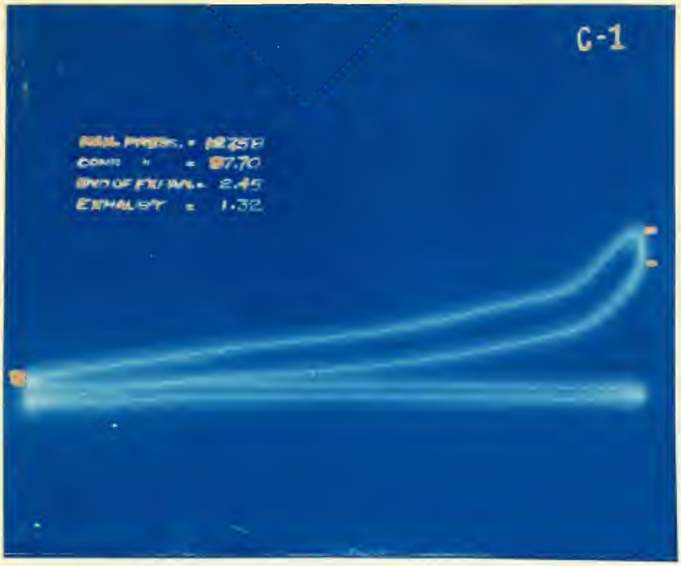
Kind of Fuel Gasoline

NO. OF RUN Run No. 1		1	2	3	4
Duration of test,	hours.	1			
Gas consumed,	lbs ~~cu. ft.~~	4.8			
Air consumed,	cu. ft.				
*Calorific value of gas, total,	B. T. U. per ~~cu. ft.~~ lbs.	20,200			
Calorific value of gas, effective,	B. T. U. ~~per cu. ft.~~ lbs.	18,700			
Jacket water supplied,	lbs.	813			
*Gas per hour,	lbs. ~~cu. ft.~~	4.8			
*Air per hour,	cu. ft.				
Jacket water per hour,	lbs.	813			
Gas at meter,	ins. mercury.				
Barometer,	ins. mercury.	2925			
Gas at engine,	ins. water.				
Jacket water Inlet,	deg. F.	35.76			
Jacket water Outlet,	deg. F.	92.61			
Gas at meter,	deg. F.	56			
Air in room,	deg. F.				
Revolutions per minute,	rev.	614.2			
Explosions per minute,		1228.4			
Pressure in lbs. per sq. in. in above atmosphere,					
(*a*) Maximum pressure,		127.58			
(*b*) Pressure just before ignition,		97.70			
(*c*) Pressure at end of expansion,		2.45			
(*d*) Exhaust pressure,		1.32			
Mean effective pressure,	lbs. per sq. in.				
Builders' Rating,	H. P.	35-40			
Actual indicated H. P.,	H. P.				
Actual brake H. P.,	H. P.	5.45			
B. T. U. per I. H. P. per hr.,					
B. T. U. per B. H. P. per hr.,		16,470			
Thermodynamic efficiency per I. H. P.,	per cent.				
Thermodynamic efficiency per B. H. P.,	per cent.	15.5			
*Cu. ft. gas per I. H. P.,					
b ~~*Cu. ft.~~ gas per B. H. P.,		.8805			
Heat equivalent of I. H. P.,	B.T.U. ~~per cent.~~	13,880	15.5%		
Heat rejected in jacket water,	B.T.U. ~~per cent.~~	46,250	51.5%		
Heat rejected in exhaust and lost through radiation and incomplete combustion,	B.T.U. per cent.	29,620	33.0%		

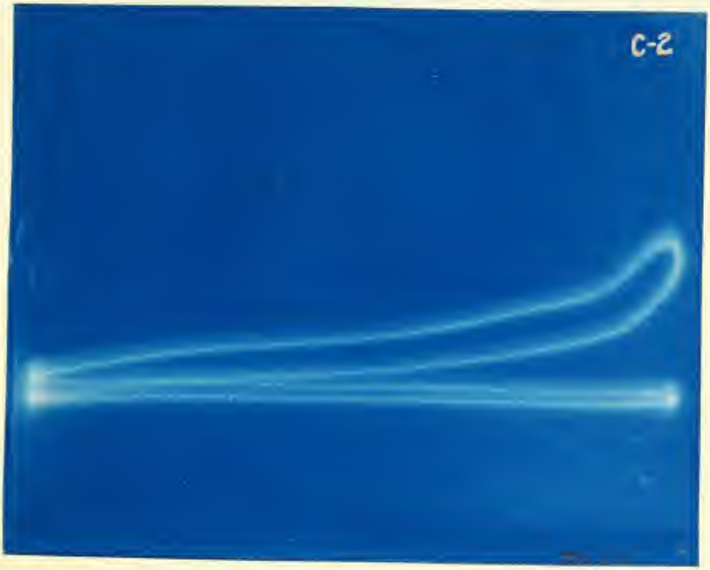
Note: These pressures are relatively correct according to indicator cards. They should be trusted no farther.

*All gas volumes reduced to 62° F. and 30 inches mercury.

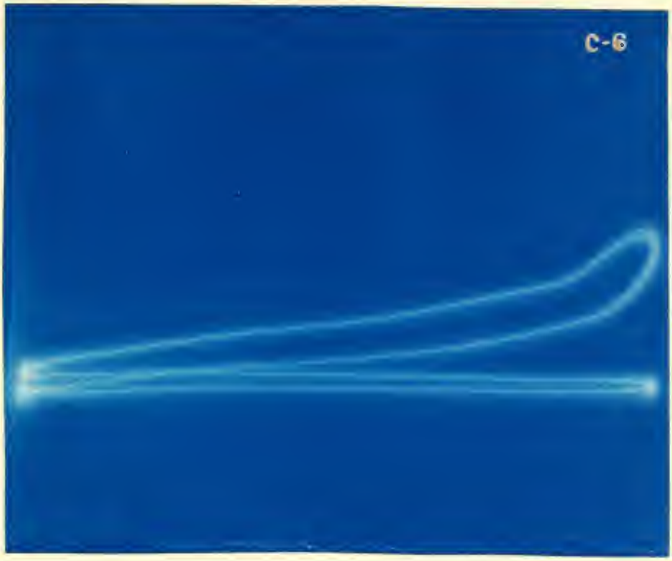
Observer M.F.Lawrence, W.C.Dunn



C-1



C-2


C-6

The Test Discussed.

Test Number One, upon which is based the lowest point of the horse-power curve, shows a gasoline consumption of 0.8805 lbs. per B.H.P. per hour. This is a rather high consumption, but not unusual when it is considered that the engine was running at about 13.6% of the rated load. This represents a heat consumption of 16,470 B.T.U. per B.H.P. hour.

The motor was run very cool, as it was in all the tests, and the heat lost to water-cooling represented 51.5% of the total B.T.U. used. Subtracting the heat equivalent of the B.H.P., the heat to exhaust and radiation was 33.0% which is, of course low since that lost to water-cooling is high.

The thermal efficiency of 15.5% based upon the B.H.P. is not bad considering the low load. The theoretical thermal efficiency is found to be 44.45%. Assuming, as a fair value, 80% mechanical efficiency (not too high in a well-built automobile engine), this gives an efficiency ratio of about 43.6%. This is, of course, based on an assumption and not to be relied upon.

The Cards Discussed.

Cards, C-1 to C-6, were taken on this test and of

these six cards, the three best ones are shown. Card C-1 shows a slightly sharper burning than the others and is a little narrower all the way through. It also shows a greater irregularity of burning than the other two, although slight. This card shows a high back-pressure. Card C-2 shows remarkable regularity of burning; a single trace representing at least three cycles. The burning is not quite as sharp as C-1, and the expansion line is slightly humped. Card C-6 is a "fatter" card than either of the others, and shows slightly less irregularity of burning than C-1, but a rounder peak than either C-1 or C-2. In general, the three cards show a low burning pressure, a fairly regular expansion and a nearly horizontal suction pressure. The cards are very regular and uniform due to the low load and slow very even running.

Using a compression pressure of 97.7 lbs. gauge calculated from the formula

$$p_d = p_c \left(\frac{V_c}{V_d}\right)^k$$

the pressures were scaled for card C-1 giving the pressures at the critical points of the card as tabulated. These pressures based as

they are upon this calculated value of compression, are incorrect, but they are correct relatively with each other within the accuracy of the manograph. As a matter of fact, the exhaust pressure was considerably more than 1.32 lbs. above atmospheric as evidenced by an increase in power upon removal of the cut-out plug in the exhaust manifold. Running with this plug removed, though giving a free exhaust, was out of the question on account of the excessive noise and gases. Therefore the high back pressure was maintained and its effect was noticeable throughout all the tests.

Test Number Two.

Index.

Conditions of Test - -- - - - - - - - page 37

Load -- - - - - - - - - - - - - - - " 37

Speed - - - - - - - - - - - - - - - " 37

Atmospheric - - - - - - - - - - - - " 37

Running Log of Test - - - - - - - - " 39

Calculations - - - - - - - - - - - - " 37

Finished Log of Test - - - - - - - - " 40

Cards - - - - - - - - - - - - - - - - - " 41 and 42

Discussion of Test - - - - - - - - - " 43

Test - - - - - - - - - - - - - - - -" 43

Cards - - - - - - - - - - - - - - " 44

The second point on our horse power curve was determinted by Test Number Two, with the brake set at a net load of 35 lbs., gross 44 lbs., and the engine running at as near 725 R.P.M. as possible.

Test Number Two was conducted under the same weather conditions as was Test Number One.

Calculations of Test Number Two.

(Refer Log Sheets, pgs. 39 and 40)

Horse Power:

$$B.H.P. = \frac{2\pi rnw}{33000}$$

r = brake arm = 1.864 feet

n = R.P.M. = 727.5 (average)

w = net brake load = 35 lbs.

$$B.H.P. = \frac{2 \times 3.1416 \times 1.864 \times 727.5 \times 35}{33,000} = 9.025$$

Gasoline Consumption:

$$\text{lbs. per B.H.P. per hr.} = \frac{7.42}{9.025} = .8220$$

Heat Consumption:

$$\text{B.T.U. per B.H.P. per hr.} = \frac{7.42 \times 18,700}{9.025} = \text{15,390 B.T.U. per B.H.P. per hr.}$$

Total B.T.U. used:

7.42 x 18,700 = 138,970 B.T.U.

B.T.U. given up to cooling:

$945(99-36) = 59,500$ B.T.U.

Percent of Total Heat to Cooling:

$\frac{59,500}{138,900} = .4284$ or 42.84 %

Heat equivalent of B.H.P.;

$9.025 \times 2545 = 23,000$ B.T.U.

Heat Lost to Radiation, Exhaust, etc.

$138,900 - (23,000+52,500) = 56,400$ B.T.U.

Percent of Total Heat to Radiation, Exhaust, etc.

$\frac{56,400}{138,900} = .406$ or 40.6 %

Thermal Efficiency; (Per B.H.P.)

$\frac{23,000}{138,900} = .1656 =$ or 16.56 %

Theoretical Thermal Efficiency:

(See Test Number One - pg.27)

$E = .4445$ or 44.45 %

MECHANICAL ENGINEERING LABORATORY
ARMOUR INSTITUTE OF TECHNOLOGY

Test of Rutenber Automobile *Gas Engine*
Type 4 cylinder - 4 cycle
Size
Fuel used Gasoline

Brake circumference, ft. arm 1.864 ft.
Dead weight of arm, lbs.
On scales, lbs. 9
Total, lbs. 9

LOG OF TEST: No.2 Barometer 29.25 Date 3-23-12.

						TEMPERATURE—DEGREES F.					PRESSURE		WEIGHTS			HORSE POW'R	
TIME	REVOLUTION COUNTER	EXPLOSIONS PER MINUTE	REVOLUTIONS PER MINUTE	GAS METER	CUBIC FEET GAS PER HR.	Entering Jacket Water	Issuing Jacket Water	Gas at Meter	Room	Exhaust	Gas at Meter, In. Mer.	At Eng., In. Water	Jacket Water	Scale Reading	Brake Load, Net	B. H. P.	I. H. P.
1:18			742		36.72	35	90.0		Tank #4 - Tare				525	44	35		
1:23			728			36	95.0							44	35		
1:28			748			36	105.0							44	35		
1:33			754			36	102.0							44	35		
1:38			721			36	103.0							44	35		
1:43			725			36	106.0							44	35		
1:48			714			36	101.5							44	35		
1:53			713			36	102.5							44	35		
1:58			690			36	102.0							44	35		
2:03			686			36	105.0							44	35		
2:08			761			36	85.0							44	35		
2:13			735			36	90.0							44	35		
2:18			740		29.30	36	96.0		Tank #4 Final				1465	44	35		

No.lbs. Gasoline used 7.42 No. lbs. water used 945

Averages			727.5		7.42	36	99						945	44	35	9.025	

REMARKS:

M.F.Lawrence, W.C.Dunn Observer.

MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

Test of ~~Rutenber Automobile~~ **Gas Engine** **Date** 3-23-12.

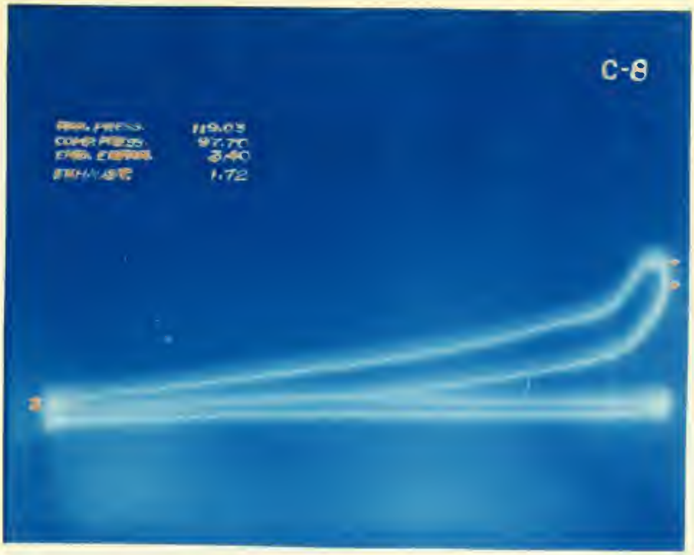
Kind of Fuel Gasoline

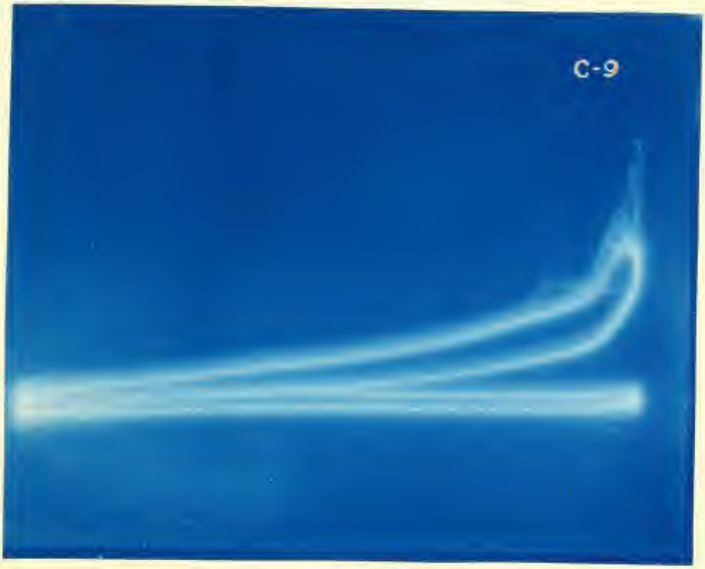
No. of Run Run No. 2		1	2	3	4
Duration of test,	hours.	1			
Gas consumed,	cu. ft.	7.42			
Air consumed,	cu. ft.				
*Calorific value of gas, total,	B. T. U. per ~~cu. ft.~~ lb.	20,200			
Calorific value of gas, effective.	B. T. U. per cu. ft.	18,700			
Jacket water supplied,	lbs.	945			
*Gas per hour,	~~cu. ft.~~ lbs.	7.42			
*Air per hour,	cu. ft.				
Jacket water per hour,	lbs.	945			
Gas at meter,	ins. mercury.				
Barometer,	ins. mercury.	29.25			
Gas at engine,	ins. water.				
Jacket water Inlet	deg. F.	36			
Jacket water Outlet,	deg. F.	99			
Gas at meter,	deg. F.				
Air in room,	deg. F.	56			
Revolutions per minute,	rev.	727.5			
Explosions per minute,		1455.0			
Pressure in lbs. per sq. in. above atmosphere					
(*a*) Maximum pressure,		119.03	*		
(*b*) Pressure just before ignition,		97.70			
(*c*) Pressure at end of expansion,		3.40			
(*d*) Exhaust pressure,		1.72			
Mean effective pressure,	lbs. per sq. in.				
Builders' rating,	H. P.	35-40			
Actual indicated H. P.,	H. P.				
Actual brake H. P.	H. P.	9.025			
Mechanical Efficiency	%				
B. T. U. per I. H. P. per hr.,					
B. T. U. per B. H. P. per hr.,		15,390			
*Cu. ft. gas per I. H. P.,					
bs ~~*Cu. ft.~~ gas per B. H. P.,		.8220			
Heat equivalent of B. H. P., efficiency	per cent.	23000			
Heat rejected in jacket water	B.TU. ~~per cent.~~	59;500	42.84 %		
Heat rejected in exhaust and lost through radiation and incomplete combustion,	B.T.U. per cent.	56,400	40,6 %		
Heat equivalent of B. H. P. efficiency	B.T.U. ~~per cent.~~	16.56	16.56 %		

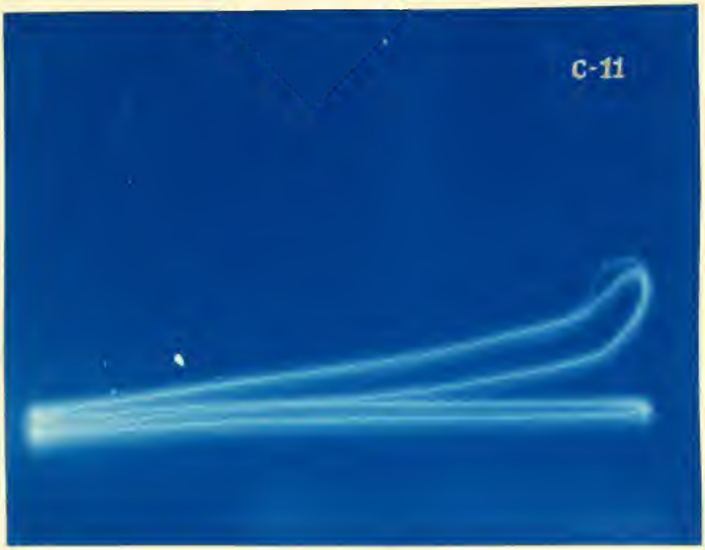
*Note: These pressures are relatively correct accord- to indicator card. They should be trusted no farther.

*All gas volumes reduced to 62° F. and 30 inches mercury.

Observer M.F.Lawrence - W.C.Dunn


C-8
COMP. PRESS.
EXHAUST
119.03
97.70
3.40
1.72


C-9


C-11

The Test Discussed.

Test Number Two, the results of which establish the second point on the horse-power curve, shows a decreased rate of gasoline, the number of pounds per B.H.P. per hour being .822 for this run as compared with .8805 lbs. per B.H.P. per hour in Test Number One. This gasoline consumption corresponds to a heat consumption of 15,390 B.T.U. per B.H.P. as compared with 16,470 B.T.U. per B.H.P. per hr., Test No. One. Thus a decrease of 1,080 B.T.U. per B.H.P. per hour, or about 6.5% is shown. The B.T.U. given up to cooling is 42.9% or about 6.8 % less than in Test Number One, and that lost in exhaust , radiation, etc. is 40.6% against 33.0 % of Test Number One, or an increase of 7.6 %. These two quantities will, of course, balance each other, an increase in one corresponding to a decrease in the other.

The thermal efficiency of this test is higher than that of Test Number One, being 16.56 % as against 15.5% of Test Number One, an increase of 1.06%. This would follow naturally, since the engine is running nearer the condition of best efficiency. The same value of the mechanical efficiency being assumed, the theoretical thermal efficiency being 44.45% as calculated in

Test Number One, gives an efficiency ratio of about 46.5 % as against 43.6 % of Test Number One. This efficiency ratio is of course subject to the same limitations of assumption as in Test Number One.

The Cards Discussed.

Of the six cards, numbered C-7 to C-12, cards C-8 and C-11 were chosen as the most representative. Card C-9 was included as interesting in that it shows a large fluctuation of the burning point due to an unstable mixture. Of the other two cards, C-8 is the best and the relative pressures were scaled from it as representing a good average of the test. Card C-8 shows much the same characteristics as Card C-1 of Test Number One. It is regular with a rounded burning point characteristic of the low load and shows the high back pressure noticeable on all the cards. Card C-11 has the same general shape as C-8, with one faulty burning trace. Its expansion line just after the peak is not quite as steep but a little farther down it takes the same general slant.

Test Number Three

Index

Condition of Test..............page 46

Load........................ " 46

Speed....................... " 46

Atmospheric................. " 46

Running Log of Test............ " 48

Calculations................... " 46

Finished Log of Test........... " 49

Cards.......................... 50 and 51

Discussion of Test............. " 52

Test........................ " 52

Cards....................... " 53

Test Number Three, determining point number three on the horse-power curve, was taken with a net load of 45 lbs., 54 lbs. gross, on the brake. The engine was run very cool, a temperature of about 85°F being maintained in the exit cooling water.

The speed was averaged at about 825 R.P.M. and the engine pulled steadily and evenly at this speed.

The weather conditions were identical with both Test Number One and Test Number Two.

Calculations of Test Number Three.

(Refer Log. Sheets, pgs. 48 and 49)

Horse Power:

$$B.H.P. = \frac{2\pi rnw}{33000}$$

r = brake arm = 1.864 ft.

n = R.P.M. = 827.3 (average)

w = net brake load = 45 lbs.

$$B.H.P. = \frac{2 \times 3.1416 \times 1.864 \times 827.3 \times 45}{33,000} = 13.21$$

Gasoline Consumption:

$$\text{lbs. per B.H.P. per hr.} = \frac{9.20}{12.21} = .6960$$

Heat Consumption:

$$\text{B.T.U. per B.H.P.} = \frac{9.20 \times 18,700}{13.21} = 13,020 \text{ B.T.U. per B.H.P. per hr.}$$

Total B.T.U. used:

9.20 x 18,700 = 172,000 B.T.U.

B.T.U. Given up to Cooling:

1492 (85.45-35.5) = 74,500 B.T.U.

Percent of Total Heat to Cooling:

$\frac{74,500}{172,000} = .4333$ or 43.33%

Heat Equivalent of B.H.P.

13.21 x 2545 = 33,650 B.T.U.

Heat Lost to Radiation, Exhaust, etc:

172,000 - (33,650 + 74,500) = 63,850 B.T.U.

Percent of Total Heat to Radiation, Exhaust, etc.

$\frac{63,850}{172,000} = .3711$ or 37.11 %

Thermal Efficiency:

$\frac{33,650}{172,000} = .1956$ or 19.56 %

Theoretical Thermal Efficiency:

(See Test Number One, pg.27)

$E = .4445$ or 44.45 %

MECHANICAL ENGINEERING LABORATORY
ARMOUR INSTITUTE OF TECHNOLOGY

Test of Rutenber Automobile *Gas Engine*	Brake Circumference, ft. arm 1.864 ft.
Type 4 cylinder - 4 cycle	Dead Weight of Arm, lbs.
Size	On Scales, lbs. 9
Fuel Used Gasoline	Total, lbs. 9

LOG OF TEST: No.3 Barometer 29.25 Date 3-23-12.

Time	Revolution Counter	Explosions Per Minute	Revolutions Per Minute	Gas Meter	Cubic Feet Gas Per Hr.	Temperature—Degrees F					Pressure		Weights			Horse Pow'r	
						Entering Jacket Water	Issuing Jacket Water	Gas at Meter	Room	Exhaust	Gas at Meter, In. Mer.	At Eng., In. Water	Jacket Water	Scale Reading	Brake Load, Net	B. H. P.	I. H. P.
3:38			830	29.00		35	71.0		Tank #4 Tare				587		54	45	
:43			802			35.0	78.0								54	45	
3:48			830			35.5	80.0								54	45	
3:53			785			36.0	85.0								54	45	
3:58			858			36:0	89.0								54	45	
4:03			819			36.0	88.0								54	45	
4:08			841			35.0	88.0								54	45	
4:13			838			35.0	89.0								54	45	
4:18			855			35.0	89.0		Tank #4 Final				1644		54	45	
									No.lbs.water used					1057			
4:23			833			35.0	88.0		Tank #5 Tare					520	54	45	
4:28			835			36.0	88.5								54	45	
4:33			820			36.0	88.0								54	45	
4:38			823	19.8		36.0	88.0		Tank #5 Final					955	54	45	
No.lbs.Gasoline used					9.20				No. lbs water used					435			
									Total No.lbs water used					1492			
Averages			827.3		9.20	35.5	85.45							1492	54	45	13.21

REMARKS

M.F.Lawrence, W.O.Dunn Observer.

MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

Test of Rutenber Automobile *Gas Engine* *Date* 3-23-12.

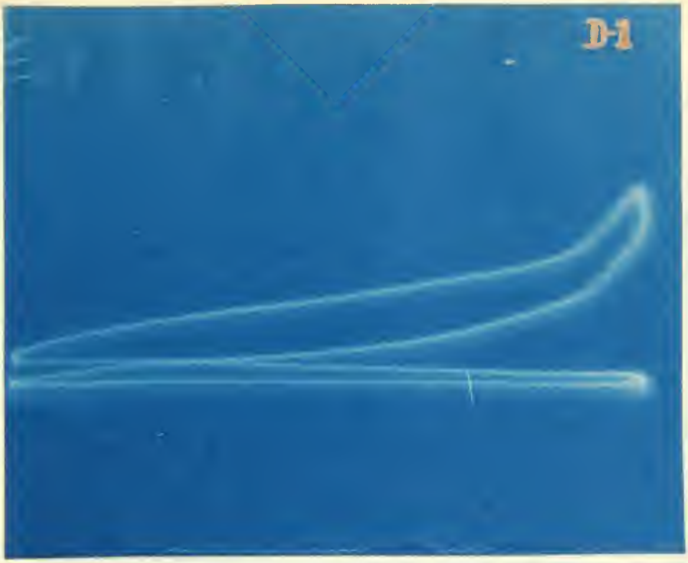
Kind of Fuel Gasoline

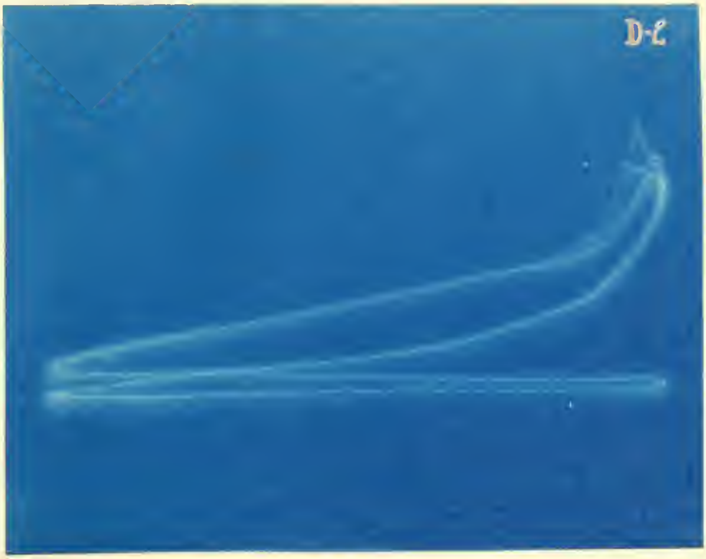
NO. OF RUN	Run No.3	1	2	3	4
Duration of test,	hours.	1			
Gas consumed,	~~cu. ft.~~ lbs.	9.2			
Air consumed,	cu. ft.				
*Calorific value of gas, total,	B. T. U. ~~per cu. ft.~~ lbs.	20,200			
Calorific value of gas, effective.	B. T. U. per ~~cu. ft.~~ lbs.	18,700			
Jacket water supplied,	lbs.	1492			
*Gas per hour,	~~cu. ft.~~ lbs.	9.2			
*Air per hour,	cu. ft.				
Jacket water per hour,	lbs.	1492			
Gas at meter,	ins. mercury.				
Barometer,	ins. mercury.	29.25			
Gas at engine,	ins. water.				
Jacket water { Inlet	deg. F.	35.50			
Jacket water { Outlet,	deg. F.	85.45			
Gas at meter,	deg. F.				
Air in room,	deg. F.	56.00			
Revolutions per minute,	rev.	827.3			
Explosions per minute,		1654.6			
Pressure in lbs. per sq. in. above atmosphere					
(*a*) Maximum pressure,		197.8 *			
(*b*) Pressure just before ignition,		97.70			
(*c*) Pressure at end of expansion,		19.88			
(*d*) Exhaust pressure,		5.65			
Mean effective pressure,	lbs. per sq. in.				
Builders' rating,	H. P.	35-40			
Actual indicated H. P.,	H. P.				
Actual brake H. P.	H. P.	13.21			
Mechanical Efficiency	%				
B. T. U. per I. H. P. per hr.,					
B. T. U. per B. H. P. per hr.,		12,020			
*Cu. ft. gas per I. H. P.,					
lbs. ~~*Cu. ft.~~ gas per B. H. P.,					
Heat equivalent of BH. P., efficiency	B.T.U. ~~per cent.~~	33,650	19.59		
Heat rejected in jacket water	B.T.U. ~~per cent.~~	74,500	43.33		
Heat rejected in exhaust and lost through radiation and incomplete combustion,	B.T.U. per cent.	63,850	37.11		
Heat equivalent of B. H. P. efficiency	per cent.	19.56			

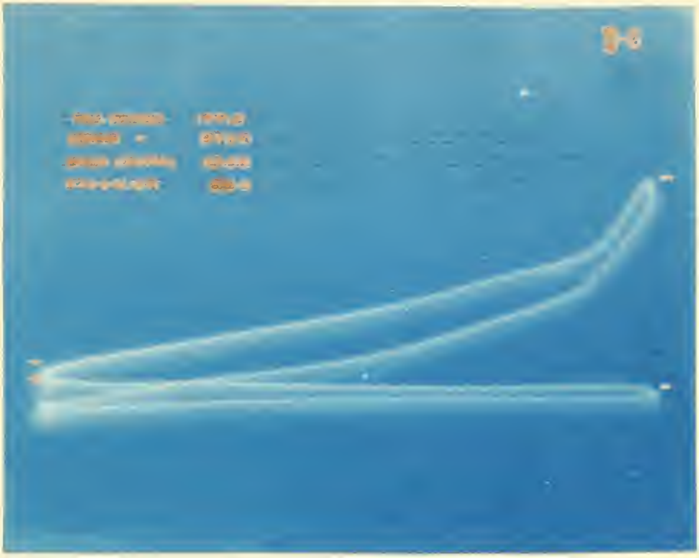
*Note: These pressures are relatively correct according to indicator cards. They should be trusted no farther.

*All gas volumes reduced to 62° F. and 30 inches mercury.

Observer M.F.Lawrence, W.C.Dunn


D-1


D-2



The Test Discussed.

In Test Number Three, the gasoline consumption rate drops considerably; from a value of .882 lbs. per B.H.P. per hr. in Test Number. Two, the consumption rate falls to .6960 lbs. per B.H.P. per hour in this test. This is equivalent to a heat consumption of 13,020, 2,370 B.T.U. per B.H.P. per hour or 15.4% less than Test Number Two.

Since the motor was run exceedingly cool, a temperature of exit cooling water of approximately 85° F, the B.T.U. loss to cooling water is high, 43.35% of the total, or about .5% more than Test Number Two. The heat lost in the exhaust, radiation, etc., is 37.13% or 3.47% less than Test Number Two. The percentage of heat converted into power is much higher than in Test Number Two.

The thermal efficiency showed a considerable increase over Experiment Number Two as might be expected. Test Number Two gave an efficiency of 16.56%, while number Three rose to 19.56%, an increase of 3.05. The efficiency ratio, based upon the assumed mechanical efficiency, 80%, and the calculated ideal thermal efficiency of 44.45%, is 55.0% which shows that the motor is rapidly approaching

its most efficient speed and load.

The Cards Discussed.

Cards, D-1 to D-6, were taken at this load and of these cards D-1, D-2, and D-3 were taken as the most representative. Card D-1 shows a considerably lower range of pressures all the way through than the others and probably was taken at an instant when the load dropped slightl.. It shows a marked improvement in the burning of the charge, however, and is a remarkably symmetrical card considering the load. Card D-2 shows better the average shape for this run, as well as a higher range of pressure, more representative of the rest of the cards. A decided iregularity of burning shows that the mixture was not as even as in Card D-2. The most satisfactory card for this test, as an average card, is D-6, which shows practically the same shape as D-2, and is very uniform. The cards all show a decided tendency to form the high "peak" of burning characteristic of the higher loads, although the engine is running at but about 38% rated load. Card D-6, then, was taken as an average card and its relative pressures figured as tabulated.

Test Number Four.

Index.

Conditions of Test.............page 54

- Load.....................page 54
- Speed....................page 54
- Atmospheric..............page 54

Running Log of Test...........page 56

Calculations..................page 54

Finished Log of Test..........page 57

Cards.........................page 58 and 59

Discussion of Test............page 61

- Test......................page 61
- Cards.....................page. 62

Test Number Four, from the results of which point number four on the horse-power curve was calculated, was run with a net brake load of 55 lbs., gross, 64 lbs. The motor was run a little warmer than during the run preceding, an average outlet cooling water temperature of 95° F being maintained.

The speed was increased and held as near 900 R.P.M. as possible, the average being 909 R.P.M.

The day was partly cloudy, there being about 6/10 sunshine, with a strong south wind blowing with an average velocity of 13 miles per hour, and the mean temperature was 32° F. The barometer was 29.16 and the room temperature about 58° F.

Calculations of Test Number Four.

Horse Power: (Refer Log Sheets, pgs.56 and 57)

$$B.H.P. = \frac{2\pi rnw}{33{,}000}$$

r = brake arm = 1.864 ft.

n = R.P.M. = 909

w = net brake load = 55 lbs.

$$B.H.P. = \frac{2 \times 3.1416 \times 1.864 \times 909 \times 55}{33{,}000} = 17.75$$

Gasoline consumption:

$$\text{lbs. per B.H.P. per hr.} = \frac{11.1 \times 60}{17.75 \times 58} = .646$$

Heat Consumption:

B.T.U. per B.H.P. per hr. = 646 x 18700 = 12,090 B.T.U. per B.H.P. per hr.

Total B.T.U. used:

11.1 x 18,700 = 207,600 B.T.U.

B.T.U. given up to cooling:

1381 (95.24-35) = 83,250 B.T.U.

Percent of Total Heating to Cooling:

$\frac{83,250}{207,600}$ = .4020 or 40.20%

Heat equivalent of B.H.P.

17.75 x. 42.42 x 58 = 43,668 B.T.U.

Heat Lost to Radiation, Exhaust, etc:

207,600-(43,668+83,250) = 80,682 B.T.U.

Percent of Total Heat to Radiation, Exhaust, etc.

$\frac{80,682}{207,600}$ = .3878 or3 8.78%

Thermal Efficiency:

$\frac{43,668}{207,600}$ = .2102 = 21.02%

Theoretical Thermal Efficiency:

(See Test Number One, pg. 27)

E. = .4445 or 44.45 %

MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

Test of Rutenber Automobile *Gas Engine*

Type 4 cylinder - 4 cycle

Size

Fuel Used Gasoline

Brake Circumference, ft. arm 1.864 ft.

Dead Weight of Arm, lbs.

On Scales, lbs. 9

Total, lbs. 9

LOG OF TEST: No.4 Barometer 29.16 Date 3;/25/12.

						TEMPERATURE—DEGREES F					PRESSURE		WEIGHTS			HORSE POW'R	
TIME	REVOLUTION COUNTER	EXPLOSIONS PER MINUTE	REVOLUTIONS PER MINUTE	GAS METER	CUBIC FEET GAS PER HR.	Entering Jacket Water	Issuing Jacket Water	Gas at Meter	Room	Exhaust	Gas at Meter, In. Mer.	At Eng., In. Water	Jacket Water	Scale Reading	Brake Load, Net	B. H. P.	I. H. P.
2:12		889			34.00	35	97.0		Tank #4 Tare				519	64	55		
2:17		932				35	105.0							64	55		
2:22		891				35	92.0							64	55		
2:27		960				35	97.0							64	55		
2:32		900				35	95.0							64	55		
2:37		924				35	96.0							64	55		
2:42		915				35	94.5							64	55		
2:47		929				35	97.0							64	55		
2:52		882				35	95.0							64	55		
2:57		909				35	95.0							64	55		
3:02		904				35	94.0							64	55		
3:07		894			22.90	35	92.0							64	55		
3:10		890				35	92.0		Tank # 4 Final				1900	64	55		
No.lbs .Gasoline used 11.10									No.lbs.water used				1381				
Averages		909			11.10	35	95.24						1381	64	55	17.75	

REMARKS

Observer.

MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

Test of Rutenber Automobile *Gas Engine* *Date* 3-25-12.

Kind of Fuel Gasoline

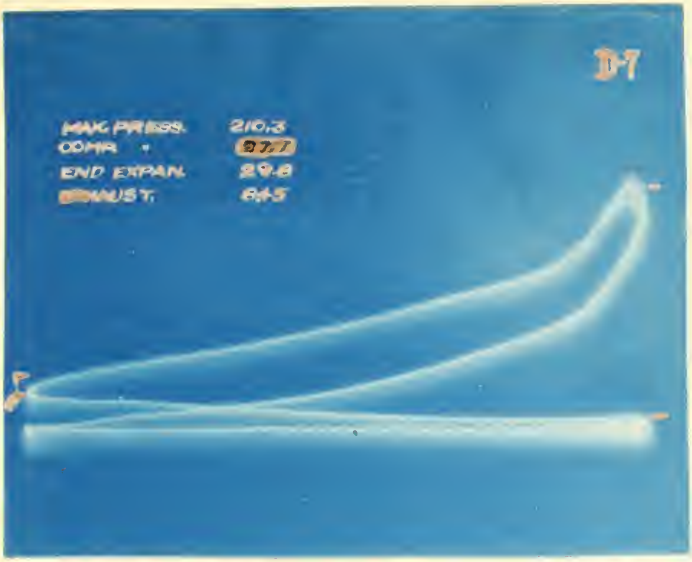
No. OF RUN Run No. 4		1	2	3	4
Duration of test,	hours.	58 min.			
Gas consumed,	~~cu. ft.~~ lbs.	11.1			
Air consumed,	cu. ft.				
*Calorific value of gas, total,	B. T. U. per ~~cu. ft.~~ lbs.	20,200			
Calorific value of gas, effective,	B. T. U. per ~~cu. ft.~~ lbs.	18700			
Jacket water supplied,	lbs.	1381			
*Gas per hour,	cu. ~~ft.~~	11.47			
*Air per hour,	cu. ft.				
Jacket water per hour,	lbs.	1430			
Gas at meter,	ins. mercury.				
Barometer,	ins. mercury.	29.16			
Gas at engine,	ins. water.				
Jacket water Inlet,	deg. F.	35.00			
Jacket water Outlet,	deg. F.	95.24			
Gas at meter,	deg. F.				
Air in room,	deg. F.	58.00			
Revolutions per minute,	rev.	909			
Explosions per minute,		1818			
Pressure in lbs. per sq. in. in above atmosphere,					
(*a*) Maximum pressure,		210.3			
(*b*) Pressure just before ignition,		97.70			
(*c*) Pressure at end of expansion,		29.8			
(*d*) Exhaust pressure,		8.45			
Mean effective pressure,	lbs. per sq. in.				
Builders' Rating,	H. P.	35 - 40			
Actual indicated H. P.,	H. P.				
Actual brake H. P.,	H. P.	17.75			
B. T. U. per I. H. P. per hr.,					
B. T. U. per B. H. P. per hr.,		12,090			
Thermodynamic efficiency per I. H. P.,	per cent.				
Thermodynamic efficiency per B. H. P.,	per cent.	21.20			
*Cu. ft. gas per I. H. P.,					
lbs. ~~*Cu.~~ ft. gas per B. H. P.,		.646			
Heat equivalent of B. H. P.,	B.T.U.& per cent.	43,668	21.00%		
Heat rejected in jacket water,	B.T.U.& per cent.	83,250	40.20%		
Heat rejected in exhaust and lost through radiation and incomplete combustion,	B.T.U.& per cent.	80.682	38.78%		

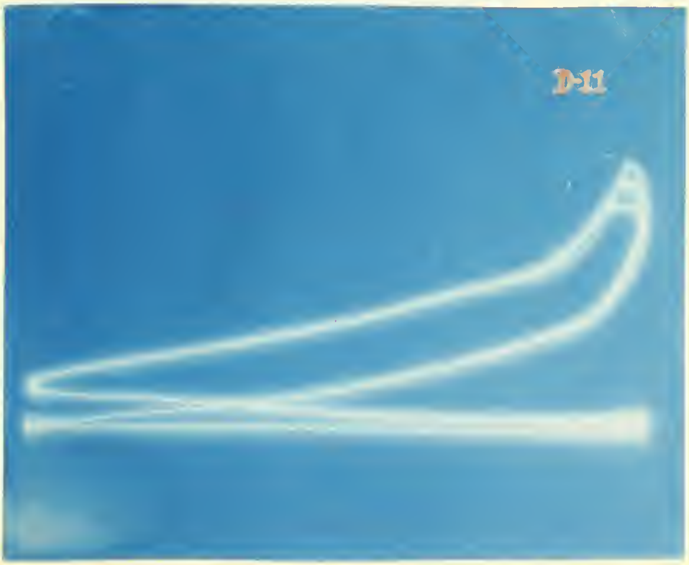
Note: These pressures are relatively correct according to indicator cards. They should be trusted no farther.

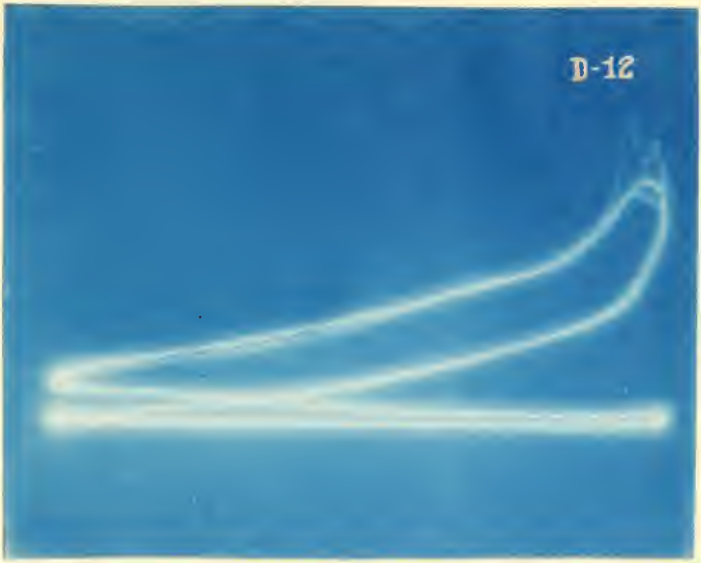
---

*All gas volumes reduced to 62° F. and 30 inches mercury.

Observer M.F.Lawrence, W.C.Dunn


D-7
MAX. PRESS. 210.3
COMP. " 87.7
END EXPAN. 29.6
EXHAUST. 6.45


D-11


D-12

The Test Discussed.

Test Number Four gave a lower rate of gasoline consumption than Number Three. The drop was not so great as between Three and Two, however, and this shows that the "knee" of the gasoline consumption curve is being approached. The gasoline consumption in this run is .646 lbs. per B.H.P. per hour, that of Run Three is 6.96 lbs., per B.H.P. per hour, showing a drop of .05 lbs. per B.H.P. per hour. This corresponds to a heat consumption of 12,090 B.T.U. per B.H.P. per hr. and 13,020 B.T.U. per B.H.P. per hr. respectively, or a drop of 930 B.T.U. per B.H.P. per hr., i.e., 7.14 %.

The engine ran slightly warmer during this run than during Test Number Three. The outlet cooling water temperature averaged 95.24°F against 85° F for Number Three. The percentage of heat to the cooling water was 40.10% in this run against 43.33% for Number Three, a difference of 3.23%. The heat to exhaust was 38.7% in this test as compared with 37.11% in Test Number Three, a difference of 1.59%.

The thermal efficiency showed an increase over that of Test Number Three, 21.20% in comparison with 19.56%, an increase of 1.64%. The efficiency ration based as before, is 59.6%.

The Cards Discussed.

The cards taken on this run numbered from D-7 to D-12, and of these D-7, D-11, and D-12 were picked as average cards. They all show a little irregularity in the burning pressures but the fluctuations are not violent. Card D-7 shows three cycles, each with a slightly different burning pressure. The rest of the card is a single line. On this card is apparent a peculiar characteristic of the upper part of the compression line, namely a peculiar fluttering. It is not very generally understood just what causes these "compression waves" as they are called, and it is yet to be satisfactorily explained. These compression waves, though the vibration is slight seem to occur on a great many of the higher load cards. It is not unlikely that they are produded by the instrument itself. Card D-7 was taken as representing an average card, the middle burning line being chosen for the average maximum pressure. The relative pressures were scaled and tabulated from this card. Card D-11 shows the irregular burning more plainly. By "irregular burning" I mean the fact that no two cycles have

same burning pressure; the burning lines themselves are smooth curves. Card D-12 shows two closely corresponding cycles and a third with faulty burning and a separate expansion line from the other two. This last cycle shows the "waves" on the burning line, similar to, though much more intensified than, those of the compression line. These, like the "compression waves" are not satisfactorily explained although one explanation is that when a faulty mixture of fuel enters the cylinder, too rich, with some of the gasoline in the form of globules, a series of small explosions follow upon the ignition of the charge, producing these waves. The heavy part of this card, D-12, is a very good average card for this run.

Test Number Five.

Index.

Conditions of Test..........pg. 65
 Load.....................pg. 65
 Speed....................pg. 65
 Atmospheric..............pg. 65
Running Log of Test.........pg. 67
Calculations................pg. 65
Finished Log of Test........pg. 68
Cards.......................pg. 69 & 70
Discussion of Test..........pg. 71
 Test.....................pg. 71
 Cards....................pg. 72

The results of Test Number Five establish the fifth point on the horse-power curve, and a net brake load of 65 lbs., 74 lbs. gross, was maintained. The motor was run at a slightly lower temperature than in Number Four, a temperature of 91° being held in the outlet cooling water.

The speed was set as near 1000 R.P.M. as possible and averaged about 1007 R.P.M. Since there was no way of air-cooling the motor, the crank case and all the lower part of the engine got hot at high loads, so that we thought it best to shorten the length of the higher loads. Thus this test was shortened to a half hour instead of a full hour.

The day was partly cloudy, 7/10 sunshine, the temperature was 39° F, barometer 29.07, with a 13 mile, west wind. The room temperature was about 61° F.

Calculations of Test Number. Five.

(Refer Log Sheets, pgs. 67 & 68)

Horse Power:

$$\text{B.H.P.} = \frac{2\pi rnw}{33000}$$

r = brake arm = 1.864 ft.

n = R.P.M. = 1007

Gasoline Consumption:

lbs. per B.H.P. per hr. $= \frac{7.45 \times 60}{23.2 \times 30} = .6425$

Heat Consumption:

B.T.U. per B.H.P. per hr. $= .6425 \times 18700 = 12000$ B.T.U. per B.H.P. per hr.

Total B.T.U. used:

$7.45 \times 18,700 = 139,400$ B.T.U.

B.T.U. given up to cooling:

$964(91.45-35) = 54,400$ B.T.U.

Percent of Total B.T.U. to cooling

$\frac{54,400}{139,400} = .390$ or 39.00 %

Heat Equivalent of B.H.P.

$23.2 \times 42.42 \times 30 = 29,520$ B.T.U.

Heat Lost to Radiation, Exhaust, etc.

$139,400 - (29,520+54,400) = 55,480$, etc.;

Percent of Total Heat to Radiation, Exhaust, etc.

$\frac{55,480}{139,400} = .3980$ or 39.80%

Thermal Efficiency:

$\frac{29,520}{139,400} = 21.20\%$

Theoretical Thermal Efficiency:

(See test Number One, pg.27)

E. = .4445 or 44.45%

MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

Test of ~~Rutenber Automobile~~ Gas Engine

Type 4 cylinder - 4 cycle

Size

Fuel Used Gasoline

Brake Circ~~umference, ft.~~ arm 1.864 ft.

Dead Weight of Arm, lbs.

On Scales, lbs. 9

Total, lbs. 9

LOG OF TEST: No.5 Barometer 29.07 Date 3-26-12.

Time	Revolution Counter	Explosions per Minute	Revolutions per Minute	Gas Meter	Cubic Feet Gas per Hr.	Temperature—Degrees F: Entering Jacket Water	Issuing Jacket Water	Gas at Meter	Room	Exhaust	Pressure: Gas at Meter, In. Mer.	At Eng., In. Water	Weights: Jacket Water	Scale Reading	Brake Load, Net	Horse Pow'r: B. H. P.	I. H. P.
2:13			1032		31.60	35	94		Tank #4 - Tare				565	74	65		
2:18			999			35	93							74	65		
2:23			998			35	94							74	65		
2:28			1038			35	96							74	65		
2:33			1004			35	89							74	65		
2:38			1011			35	88							74	65		
2:43			965		24.15	35	86		Tank #4 Final				1529	74	65		
No.lbs.Gasoline Used 7.45									No.lbs.Water used				964				
Averages			1007		7.45	35	91.45						964	74	65	23.2	

REMARKS

M.F.Lawrence, W.C.Dunn

Observer.

MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

Test of Rutenber Automobile ***Gas Engine*** ***Date*** 3-26-12

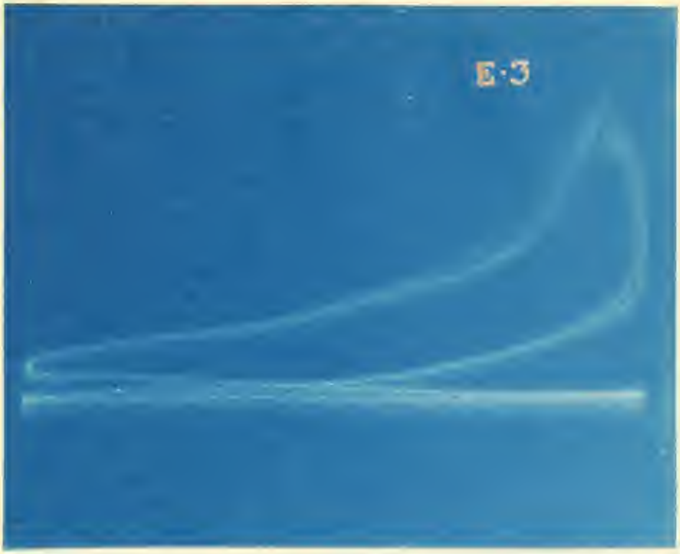
Kind of Fuel Gasoline

NO. OF RUN Run No. 5		1	2	3	4
Duration of test,	hours.	30 mins.			
Gas consumed,	~~cu. ft.~~ lbs.	7.45			
Air consumed,	cu. ft.				
*Calorific value of gas, total,	B. T. U. per ~~cu. ft.~~ lb.	20,200			
Calorific value of gas, effective.	B. T. U. per ~~cu. ft.~~ lb.	18,700			
Jacket water supplied,	lbs.	964			
*Gas per hour,	~~cu. ft.~~ lbs.	1928			
*Air per hour,	cu. ft.				
Jacket water per hour,	lbs.	1928			
Gas at meter,	ins. mercury.				
Barometer,	ins. mercury.	29.07			
Gas at engine,	ins. water.				
Jacket water, Inlet	deg. F.	35			
Jacket water, Outlet,	deg. F.	91.45			
Gas at meter,	deg. F.				
Air in room,	deg. F.	61.0			
Revolutions per minute,	rev.	1007			
Explosions per minute,		2014			
Pressure in lbs. per sq. in. above atmosphere					
(*a*) Maximum pressure,		270.2			
(*b*) Pressure just before ignition,		97.70			
(*c*) Pressure at end of expansion,		25.6			
(*d*) Exhaust pressure,		11.4			
Mean effective pressure,	lbs. per sq. in.				
Builders' rating,	H. P.	35-40			
Actual indicated H. P.,	H. P.				
Actual brake H. P.	H. P.	23.20			
Mechanical Efficiency	%				
B. T. U. per I. H. P. per hr.,					
B. T. U. per B. H. P. per hr.,		12,000			
*Cu. ft. gas per I. H. P.,					
*~~Cu. ft.~~ lbs gas per B. H. P.,		.6425			
Heat equivalent of I. H. P., efficiency	B.T.U per cent.	29,520	21.20%		
Heat rejected in jacket water	B.T.U per cent.	54,400	39.00%		
Heat rejected in exhaust and lost through radiation and incomplete combustion,	B.T.U. per cent.	55,480	39.80%		
Heat equivalent of B. H. P. efficiency	per cent.	29,520	21.20%		

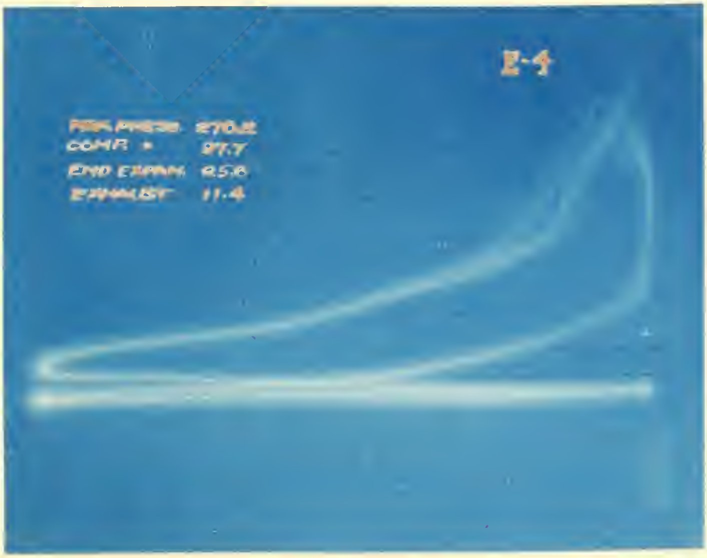
Note: These pressures are relatively correct according to indicator cards. They should be trusted no farther.

*All gas volumes reduced to 62° F. and 30 inches mercury.

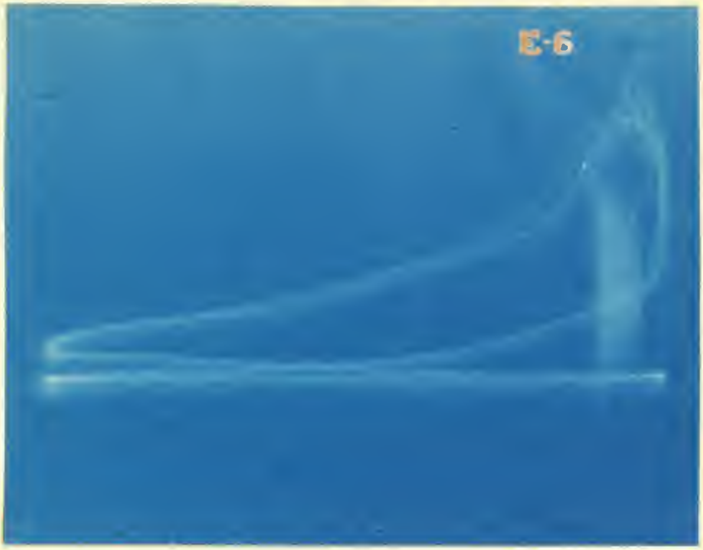
Observer M. F. Lawrence, W. C. Dunn



E·3



E-4


E-6

The Test Discussed.

The gasoline consumption rate in Test Number Five was lower than that in Test Number Four, .6425 lbs. per B.H.P. per hr. against .646 lbs. per B.H.P. per hour, a difference of .0015 lbs. which is very small. These correspond to a heat consumption of 12,000 B.T.U. per B.H.P. per hr. and 12,090 B.T.U. per B.H.P. per hr. respectively, the difference being 90 B.T.U. per B.H.P. per hr., or 0.745%.

The engine was run slightly cooler during this run that in Number Four. The outlet cooling water was 91° F while during Test Number Four it was 95°F. The heat given up to cooling water was slightly less than in Number Four, 39.0% against 40.20%, or a decrease of 1.2%. The heat to Exhaust, Radiation, etc. was a little higher than in Test Number Four, 39.8% against 38.78%, an increase of 1.02%.

The thermal efficiency in this test is slightly higher than in Number Four, though very little. It is 21.2% in this one and in Number Four it was 21.02, an increase of .18% in Number Five. The efficiency ratio, as in Number Four, is practically the same.

The Cards Discussed.

Cards E-1 and E-6 are from Test Number Five and of these, the average cards selected are E-3, E-4, and E-5. Of these there is no one particularly better than the others, although card E-4 seems to be a little more clearly defined, and this card was taken as the average, and the pressures scaled. Card E-3 taken at fairly high speed shows a network of lines from the end of compression to the middle of expansion, but the shape of the card is fairly clear. The network shows that the mixture, though set carefully by hand, could not have been uniform. The late combustion indicates this also. There are three causes which might be responsible for this late and somewhat non-uniform burning. A late spark might produce the effect, an improper mixture of air and gasoline might also be responsible, and in another case, an excess of exhaust gases would hinder combustion. Of the three, the last seems the most likely. The spark was well advanced as evidenced by the distinct ignition point on the curve, the mixture was adjusted carefully by hand, and a high back pressure due to the length and conditions of the exhaust pipe was known to exist,

causing a very probable check to the exit of the exhaust gases. Cards E-4 and E-6 are very similar to E-3 and show practically the same effects. The streak noticeable across the compression line on card E-6 is due to leakage of light.

Test Number Six.

Index.

Conditions of Test --------------------page 75

Load -------------------------- 75

Speed -------------------------- 75

Atmospheric. ---------------------- 75

Running Log of Test --------------------- 78

Calculations -------------------------- 75

Finished Log of Test --------------------- 79

Cards ------------------------------- 80

Discussion of Test ----------------------- 80

Test ------------------------------ 80

Cards ------------------------------ 80

Test Number Six determines the sixth point on the horse-power curve, and was taken with a net brake load of 75 lbs, 84 lbs. gross. The engine ran a little warmer than in the previous run, the outlet cooling water being at an average temperature of 96 degrees F.

The speed was held as near 1100 R.P.M. as possible and averaged about 1119 R.P.M. This run was also held for 30 minutes.

The day was cloudy, 4/10 sunshine, and the average temperature was 41° F. There was an 8-mile southwest wind and the barometer read 29.15. The room temperature was 63.5° F.

Calculations of Test Number Six.

(Refer Log Sheets, Pgs. 78 and 79)

Horse Power;

$$B.H.P. = \frac{2\pi R N W}{33000}$$

r = brake arm = 1.864 ft.

n = R.P.M. = 1119

w = net brake load = 75 lbs.

$$B.H.P. = \frac{2 \times 3.1416 \times 1119 \times 75 \times 1.864}{33000} = 29.77$$

Gasoline Consumption:

$$\text{lbs. per B.H.P. per hr.} = \frac{8.83 \times 60}{29.77 \times 30} = .5940$$

Heat Consumption:

B.T.U. per B.H.P. per hr. = .5940 x 18700 = 11,100

B.T.U. per B.H.P. per hour.

Total B.T.U. used:

8:83 x 18700 = 165200 B.T.U.

B.T.U. given up to Cooling:

1022 (96-35) = 62400 B.T.U.

Percent of Total B.T.U. to Cooling:

$$\frac{62400}{165200} = .3770 \text{ or } 37.70\%$$

Heat equivalent of B.H.P.

29.77 x 42.42 x 30 = 37800 B.T.U.

Heat lost to Radiation, Exhaust, etc.:

165200 - (37800 + 62400) = 65000 B.T.U.

Percent of Total B.T.U. to Radiation, Exhaust, etc.:

$$\frac{65000}{165200} = .3941 \text{ or } 39.41\%$$

Thermal Efficiency:

$$\frac{37800}{165200} = .2289 \text{ or } 22.89\%$$

Theoretical Thermal Efficiency:

(See Test Number One, page 27)

$E = .4445$ or 44.45%

MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

Test of Rutenber Automobile Gas Engine

Type 4 cylinder - 4 cycle

Size

Fuel Used Gasoline

Brake ~~Circumference, ft.~~ arm 1.864 ft

Dead Weight of Arm, lbs.

On Scales, lbs. 9

Total, lbs. 9

LOG OF TEST: No.6 Barometer 29.15 Date 3-27-12.

Time	Revolution Counter	Explosions Per Minute	Revolutions Per Minute	Gas Meter	Cubic Feet Gas Per Hr.	Temperature—Degrees F					Pressure		Weights			Horse Pow'r	
						Entering Jacket Water	Issuing Jacket Water	Gas at Meter	Room	Exhaust	Gas at Meter, In. Mer.	At Eng., In. Water	Jacket Water	Scale Reading	Brake Load, Net	B. H. P.	I. H. P.
2:25			936		30.55	35	96.0		Tank #4 - Tare				567	84	75		
2:30			1260			35	105.0							84	75		
2:35			1059			35	93.0							84	75		
2:40			1090			35	93.0							84	75		
2:45			1160			35	94.5							84	75		
2:50			1235			35	96.5							84	75		
2:55			1093		21.72	35	93.0		Tank #4 Final				1589	84	75		
No.Lbs.Gasoline					8.83				No.lbs.water used				1022				
verages:			1119		8.83	35	96						1022	84	75	29.77	

REMARKS

M.F.Lawrence, W.C.Dunn Observer.

MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

Test of Rutenber Automobile *Gas Engine* *Date* 3-27-12.

Kind of Fuel Gasoline.

No. of Run	Run No. 6	1	2	3	4
Duration of test,	hours.	30 mins.			
Gas consumed,	~~cu. ft.~~	lbs. 8.82			
Air consumed,	~~cu. ft.~~	lbs. ,			
*Calorific value of gas, total,	B. T. U. per ~~cu. ft.~~	lbs. 20,200			
Calorific value of gas, effective.	B. T. U. per ~~cu. ft.~~	Lbs. 18,700			
Jacket water supplied,	lbs.	1022			
*Gas per hour,	~~cu. ft.~~	lbs. 17.66			
*Air per hour,	cu. ft.				
Jacket water per hour,	lbs.	2044			
Gas at meter,	ins. mercury.				
Barometer,	ins. mercury.	29.15			
Gas at engine,	ins. water.				
Jacket water: Inlet	deg. F.	35			
Jacket water: Outlet,	deg. F.	96			
Gas at meter,	deg. F.				
Air in room,	deg. F.	63.5			
Revolutions per minute,	rev.	1119			
Explosions per minute,		2238			
Pressure in lbs. per sq. in. above atmosphere					
(*a*) Maximum pressure,					
(*b*) Pressure just before ignition,		97.70			
(*c*) Pressure at end of expansion,					
(*d*) Exhaust pressure,					
Mean effective pressure,	lbs. per sq. in.				
Builders' rating,	H. P.	35-40			
Actual indicated H. P.,	H. P.				
Actual brake H. P.	H. P.	29.77			
Mechanical Efficiency	%				
B. T. U. per I. H. P. per hr.,					
B. T. U. per B. H. P. per hr.,		11,100			
*Cu. ft. gas per I. H. P.,					
lbs. *~~Cu.~~ ft. gas per B. H. P.,		.5940			
Heat equivalent of I. H. P., efficiency	B. T. U. & per cent.	37,800	22.89%		
Heat rejected in jacket water	B. T. U. & per cent.	62,400	37.70%		
Heat rejected in exhaust and lost through radiation and incomplete combustion,	B. T. U. & per cent.	65,000	39.41%		
Heat equivalent of B. H. P. efficiency	per cent.	22.89 %			

*All gas volumes reduced to 62° F. and 30 inches mercury.

Observer M. F. Lawrence, W. C. Dunn

Unfortunately the plates upon which the cards for this run were taken, were destroyed. The water in which the plates were washed occasionally ran hot. This was not discovered until after the plates were destroyed. The water would run perfectly cold for three or four hours at a time and then suddenly turn hot for a few minutes. The plates for run number six happened to be in the wash during one of these spells. When th the plates were taken out the water had turned cold again and the cause of the loss of the plates was mystifying until, upon letting the water run some hours longer, it turned warm again and we discovered the fact.

The Test Discussed.

The fuel consumption dropped markedly in Test Number Six, falling to .5940 lbs. per B.H.U. per hr., a difference of .0485 lbs. per B.H.P. per hr. Expressed in heat units, Number Six gasoline consumption rate is 11,100 B.

B.T.U. per B.H.P. per hr. and that of Test Number Five is 12,000 B.T.U. per B.H.P. per hr., a difference of 900 B.T.U. per B.H.P. per hr. or 7.50%. This is a remarkably good economy and is nearly as low a consumption rate as our tests showed.

A slightly higher temperature of outlet cooling water was maintained in this test; this temperature was 96° F, as a average, against 91° F in Test Number Five. The heat given up to the cooling water in Test Number Six was 37.70% against 39.0% in Test Number Five, a difference of 1.3%. The percentage of heat lost in radiation exhaust, etc., in Mumber Six was 39.41%, in Number Five, 39.8%, practically the same.

As would be expected from the drop~~s~~ in the fuel consumption, an increase in thermal efficiency took place. This value was 22.89% in Test Number Six, compared with 21.20% in Test Number Five, an increase of 1.69% which

is of considerable importance when the high value of the efficiency is considered. With the assumed values of mechanical efficiency and ideal thermal efficiency as in Test Number One, this gives an efficiency ratio of 64.5% which is exceedingly good. This value, as stated before, however, cannot be relied upon, since based on assumptions.

Test Number Seven.

Index.

Conditions of Test..................Page 84

  Load........................ 84

  Speed........................ 84

  Atmospheric.................. 84

Running Log of Test............... 86

Calculations...................... 84

Finished Log of Test.............. 87

Cards............................. 88

Discussion of Test................ 89

  Test........................ 89

  Cards........................ 90

Test Number Seven represents the seventh point on the horse-power curve. The net brake load was 85 lbs., corresponding to 94 lbs. gross. In order to keep the engine as cool as possible we lowered the outlet cooling water temperature to 87.4° F, average.

The speed was held near 1150 R.P.M., the average for the run being 1160 R.P.M. On account of excessive heating of the crank case and of the other parts of the engine not cooled by the water jackets we shortened the length of the run to a quarter of an hour.

The weather conditions were those s stated in Test Number Six.

Calculations of Test Number Seven.

(Refer Log Sheets, Pages86 and 87)

Horse Power;

$$B.H.P. = \frac{2\pi r n w}{33000}$$

r = brake arm = 1.864 ft.

n = R.P.M. = 1160

W = Net brake load = 85 lbs.

$$B.H.P. = \frac{2 \times 3.1416 \times 1.864 \times 1160 \times 85}{33000} = 35.00$$

Gasoline Consumption;

lbs. per H.H.P. per hr $= \frac{5.19 \times 60}{35.0 \times 15} = .593$

Heat Consumption;

B.T.U.per B.H.P. per hr. = .593 x 18700

equals 11,080 B.T.U. per B.H.P. per hr.

Total B.T.U. used;

5.19 x 18700 = 97000 B.T.U.

B.T.U: given up to cooling;

617 (87.4 - 34.4) = 32700 B.T.U.

Percent of Total B.T.U. to Cooling;

$\frac{32700}{97000} = .337$ or 33.7%

Heat Equivalent of B.H.P.;

35.0 x 42.42 x 15 = 22270 B.T.U.

Heat Lost to Radiation, Exhaust, etc.;

97000 - (22270 + 32700) = 42030 B.T.U.

Percent of Total Heat to Radiation, Exhause etc.;

$\frac{42030}{97000} = .4338$ of 43.38%

Termal Efficiency; $\frac{22270}{97000} = 22.92\%$

Theoratical Thermal Efficiency;

(See test Number One, page. 27)

E = .4445 or 44.45%

MECHANICAL ENGINEERING LABORATORY
ARMOUR INSTITUTE OF TECHNOLOGY

Test of Rutenber Automobile *Gas Engine*
Type 4 Cylinder - 4 cycle
Size
Fuel Used Gasoline

Brake ~~Circumferen~~ce, ft. arm 1.864 ft.
Dead Weight of Arm, lbs.
On Scales, lbs. 9
Total, lbs. 9

LOG OF TEST: No. 7 Barometer 29.15 Date 3-27-12.

						TEMPERATURE—DEGREES F					PRESSURE		WEIGHTS			HORSE POW'R	
TIME	REVOLUTION COUNTER	EXPLOSIONS PER MINUTE	REVOLUTIONS PER MINUTE	GAS METER	CUBIC FEET GAS PER HR.	Entering Jacket Water	Issuing Jacket Water	Gas at Meter	Room	Exhaust	Gas at Meter, In. Mer.	At Eng., In. Water	Jacket Water	Scale Reading	Brake Load, Net	B. H. P.	I. H. P.
3:21			1230		34.84	35.0	88	Tank # 4 - Tare -					566	94	85		
3:23			1186			35.0	88							94	85		
3:25			1154			34.0	88							94	85		
3:27			1137			34.0	87							94	85		
3:29			1177			34.5	87							94	85		
3:31			1123			34.5	87							94	85		
3:33			1120			34.0	87							94	85		
3:36			1118		29.65	34.0	87	Tank #4 Final					1183	94	85		
	No. lbs. Gasoline used				5.19			No.lbs.water used					617				
Averages:			1160		5.19	34.4	87.4						617	94	85	35.00	

REMARKS

M.F.Lawrence, W.C.Dunn
Observer.

MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

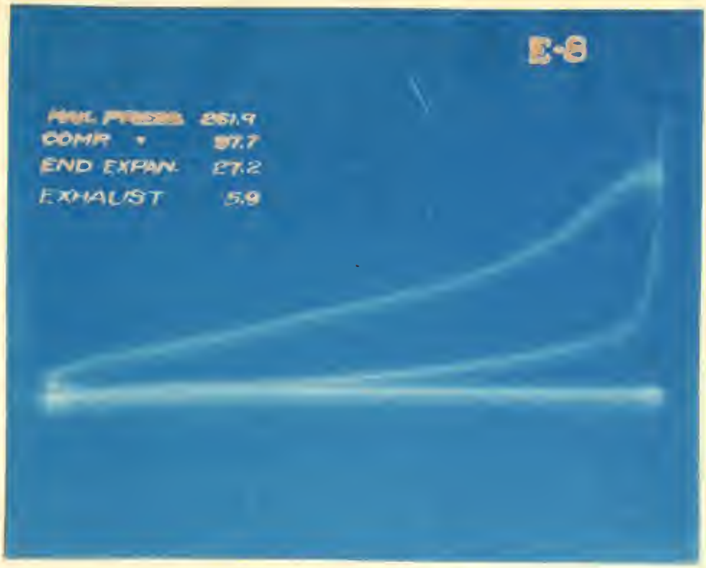
Test of ~~Rutenber Automobile~~ **Gas Engine** **Date** 3-27-12

Kind of Fuel Gasoline

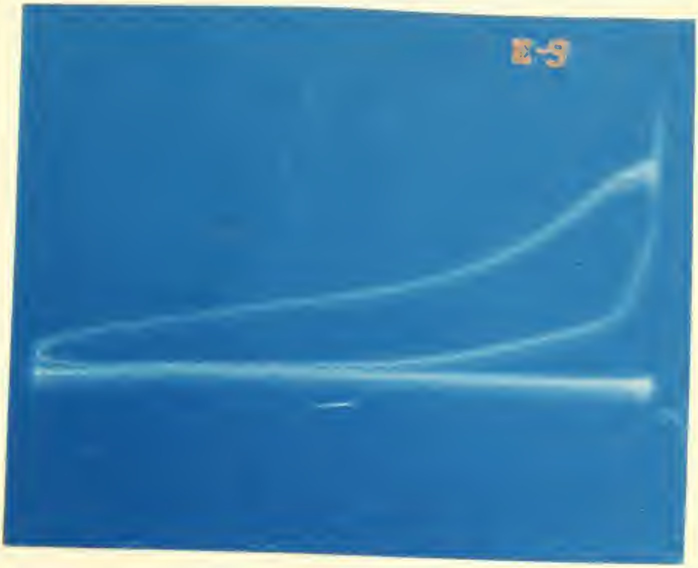
No. of Run	Run No. 7	1	2	3	4
Duration of test,	hours.	15 mins.			
Gas consumed,	~~cu. ft.~~ lbs.	5.19			
Air consumed,	cu. ft.				
*Calorific value of gas, total,	B. T. U. per ~~cu. ft.~~ lb.	20,200			
Calorific value of gas, effective.	B. T. U. per ~~cu. ft.~~ lb.	18,700			
Jacket water supplied,	lbs.	617			
*Gas per hour,	cu. ft.	20.76			
*Air per hour,	cu. ft.				
Jacket water per hour,	lbs.	2468			
Gas at meter,	ins. mercury.				
Barometer,	ins. mercury.	29.15			
Gas at engine,	ins. water.				
Jacket water, Inlet	deg. F.	34.4			
Jacket water, Outlet,	deg. F.	87.4			
Gas at meter,	deg. F.				
Air in room,	deg. F.	63.5			
Revolutions per minute,	rev.	1160			
Explosions per minute,		2320			
Pressure in lbs. per sq. in. above atmosphere					
(a) Maximum pressure,		261.9	Note: These pressures are relatively correct according to indicator cards. They should be trusted no farther.		
(b) Pressure just before ignition,		97.7			
(c) Pressure at end of expansion,		27.2			
(d) Exhaust pressure,		5.9			
Mean effective pressure,	lbs. per sq. in.				
Builders' rating,	H. P.	35 - 40			
Actual indicated H. P.,	H. P.				
Actual brake H. P.	H. P.	35			
Mechanical Efficiency	%				
B. T. U. per I. H. P. per hr.,					
B. T. U. per B. H. P. per hr.,		11,080			
*Cu. ft. gas per I. H. P.,					
~~*Cu. ft.~~ gas per B. H. P.,		.593			
Heat equivalent of I. H. P., efficiency	B.T.U.& per cent.	22,270	22.92%		
Heat rejected in jacket water	B.T.U.& per cent.	32,700	33.70%		
Heat rejected in exhaust and lost through radiation and incomplete combustion,	B.T.U.& per cent.	42,030	43.38%		
Heat equivalent of B. H. P. efficiency	per cent.	22.92 %			

*All gas volumes reduced to 62° F. and 30 inches mercury.

Observer M.F.Lawrence W.C.Dunn



E-8



E-9

The Test Discussed.

The gasoline consumption of Test Number Seven is very slightly lower than that of Test Number Six, .593 lbs. per B.H.P. per hr. as compared with .544 lbs per B.H.P. per hr. in Test Number Six. Expressed in heat unite per B.H.P. per hr. these are respectively, 11,080 B.T.U. per B.H.P. per hr. and 11100 B.T.U. per B.H.P. per hr, a decrease of 20 B.T.U. per B.H.P. per hr., or .18%. Evidently the engine is running at about its best economy.

The outlet cooling water temperature for this run was lowered to 87.4°F as compared with 96° F of Test Number Six. The heat given up to cooling water in this run was 33.7% against 37.7% in Test Number Six, a decrease of 4.0%. The percentage of heat lost in radiation, exhaust, etc., in Test Number Seven was 43.38% that in Test Number Six, 39.41%, an increase

of 3.97%.

The thermal efficiency in this test was raised to 22.92% as compared with 22.89% in Test Number Six, an increase of 0.03%. As this increase is very slight, the thermal efficency ratio, based as inthe previous tests is practically the same.

The Cards Discussed.

Cards E-8 and E-9 were taken on this run and they are, all things considered, the best cards obtained from the engine. They are practically identical in shape, showing even running of the engine at its most satisfactory load under the existing conditions. A sharp high burning peak, followed by an even expansion line, a fairly low back pressure line, and a smooth compression line, together with a well-defined ignition point are characteristic of both cards. If any discrimination is to be shown, card E-8 is a little better than E-9, having a little better com-

pression line. This card, taken as the average for this load, was sealed for the relative pressures tabulated upon it.

Test Number Eight.

Index.

Conditions of Test.................Page 93

Load........................ 93

Speed....................... 93

Atmospheric.................. 93

Running Log of Test............... 96

Calculations..................... 94

Finished Log of Test.............. 97

Cards............................ 98

Discussion of Test................ 98

Test......................... 98

Cards........................ 98

Test Number Eight represents the eighth point on the horse-power curve. It was run with a net brake load of 90 lbs., gross 99 lbs., being the highest load the engine would pull at this speed. The cooling water temperature was allowed to rise to 99.9° F as we intended taking only a very short run.

The speed was held near 1100 R.P.M., 1106.33 R.P.M. being the average for the test. Conditions in the labratory made it advisable to keep the speed of the engine under 1200 R.P.M. and in this run we were obtaining the highest horse-power the engine would develop at this speed. The run was limited to 5 minutes on account of the difficulty of keeping the engine at constant speed with the heavy load.

The weather conditions were those g given in Test Number Six.

Calculations of Test Number Eight.

(Refer Log Sheets, pages 96and97)

Horse Power; $\text{B.H.P.} = \dfrac{2\pi r\, n\, w}{33000}$

r = brake arm = 1.864 ft.

n = R.P.M. = 1106.33

w = Net brake load = 90 lbs.

$$\text{B.H.P.} = \frac{2 \times 3.1416 \times 1.864 \times 1106.33 \times 90}{33000} = 35.30$$

Gasoline Consumption;

$$\text{lbs. per B.H.P. per hr.}\ \frac{2.30 \times 60}{35.3 \times 5.5} = .711$$

Heat Consumption;

B.T.U. per B.H.P. per hr = .711 x 18700 = 13300

B.T.U. per B.H.P. per hr.

Total B.T.U. used. = 2.30 x 18700 = 43000 B.T.U.

B.T.U. given up to Cooling; 224 (99.9 - 35) = 14540 B.T.U.

Percent of Total B.T.U. to Cooling;

$$\frac{14540}{43000} = .3480 \text{ or } 34.80\%$$

Heat Equivalent of B.H.P.

35.3 x 42.42 x 5.5 = 8,230 B.T.U.

Heat Lost to Radiation, Exhause, etc.p

43000 - (8230 + 14540) = 20230 B.T.U.

Percent of Total Heat to Radiation, Exhaust, etc.;

$$\frac{20230}{43000} = .4604 \text{ or } 46.04\%$$

Thermal Efficiency;

$$\frac{8230}{43000} = .1916 \text{ or } 19.16\%$$

Theoretical Thermal Efficiency;

(See Test Number One, page 27)

E equals .4445 or 44.45%

MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

Test of Rutenber Automobile *Gas Engine*
Type 4 cylinder -4eycle
Size
Fuel Used Gasoline

Brake ~~Circumference~~, ft. arm 1.864 ft.
Dead Weight of Arm, lbs.
On Scales, lbs. 9
Total, lbs. 9

LOG OF TEST: No.8 Barometer 29.15 Date 3/27/12.

						TEMPERATURE—DEGREES F					PRESSURE		WEIGHTS			HORSE POW'R	
TIME	REVOLUTION COUNTER	EXPLOSIONS PER MINUTE	REVOLUTIONS PER MINUTE	GAS METER	CUBIC FEET GAS PER HR.	Entering Jacket Water	Issuing Jacket Water	Gas at Meter	Room	Exhaust	Gas at Meter, In. Mer.	At Eng., In. Water	Jacket Water	Scale Reading	Brake Load, Net	B. H. P.	I. H. P.
9:49			1119		26.75	35	98		Tank #4		Tare		560	99	90		
9:52			1092			35	101							99	90		
9:54			1108			35	100							99	90		
9:54-30			1098		24.45	35	100		Tank #4		Final		784	99	90		
No. lbs. Gasoline					2.30				No. lbs. water used				224				
Averages			1106.33		2.30	35	99.9						224	99	90	35.3	

REMARKS

M.F.Lawrence, W.C.Dunn
Observer.

MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

Test of Rutenber Automobile *Gas Engine* *Date* 3-27-12.

Kind of Fuel Gasoline

NO. OF RUN Run No. 8		1	2	3	4
Duration of test,	hours.	5½ mins.			
Gas consumed,	~~cu. ft.~~	lbs. 2.3			
Air consumed,	cu. ft.				
*Calorific value of gas, total,	B. T. U. ~~per cu. ft.~~	lbs.20,200			
Calorific value of gas, effective.	B. T. U. ~~per cu. ft.~~	-lbs.18,700			
Jacket water supplied,	lbs.	224			
*Gas per hour,	cu. ft.	25.1			
*Air per hour,	cu. ft.				
Jacket water per hour,	lbs.	2460			
Gas at meter,	ins. mercury.				
Barometer,	ins. mercury.	29.15			
Gas at engine,	ins. water.				
Jacket water { Inlet	deg. F.	35.0			
Jacket water { Outlet,	deg. F.	99.9			
Gas at meter,	deg. F.				
Air in room,	deg. F.	63.5			
Revolutions per minute,	rev.	1106.33			
Explosions per minute,		2212.66			
Pressure in lbs. per sq. in. above atmosphere					
(*a*) Maximum pressure,					
(*b*) Pressure just before ignition,					
(*c*) Pressure at end of expansion,					
(*d*) Exhaust pressure,					
Mean effective pressure,	lbs. per sq. in.				
Builders' rating,	H. P.	35 - 40			
Actual indicated H. P.,	H. P.				
Actual brake H. P.	H. P.	35.30			
Mechanical Efficiency	%				
B. T. U. per I. H. P. per hr.,					
B. T. U. per B. H. P. per hr.,		13,300			
*Cu. ft. gas per I. H. P.,					
lbs. *~~Cu. ft.~~ gas per B. H. P.,		.711			
Heat equivalent of I. H. P., efficiency	B.T.U. per cent.	8230	19.16%		
Heat rejected in jacket water	B.T.U. per cent.	14,540	34.80%		
Heat rejected in exhaust and lost through radiation and incomplete combustion,	B.T.U. per cent.	20,230	46.04%		
Heat equivalent of B. H. P. efficiency	per cent.	19.16			

*All gas volumes reduced to 62° F. and 30 inches mercury.

Observer M.F.Lawrence, W.C.Dunn

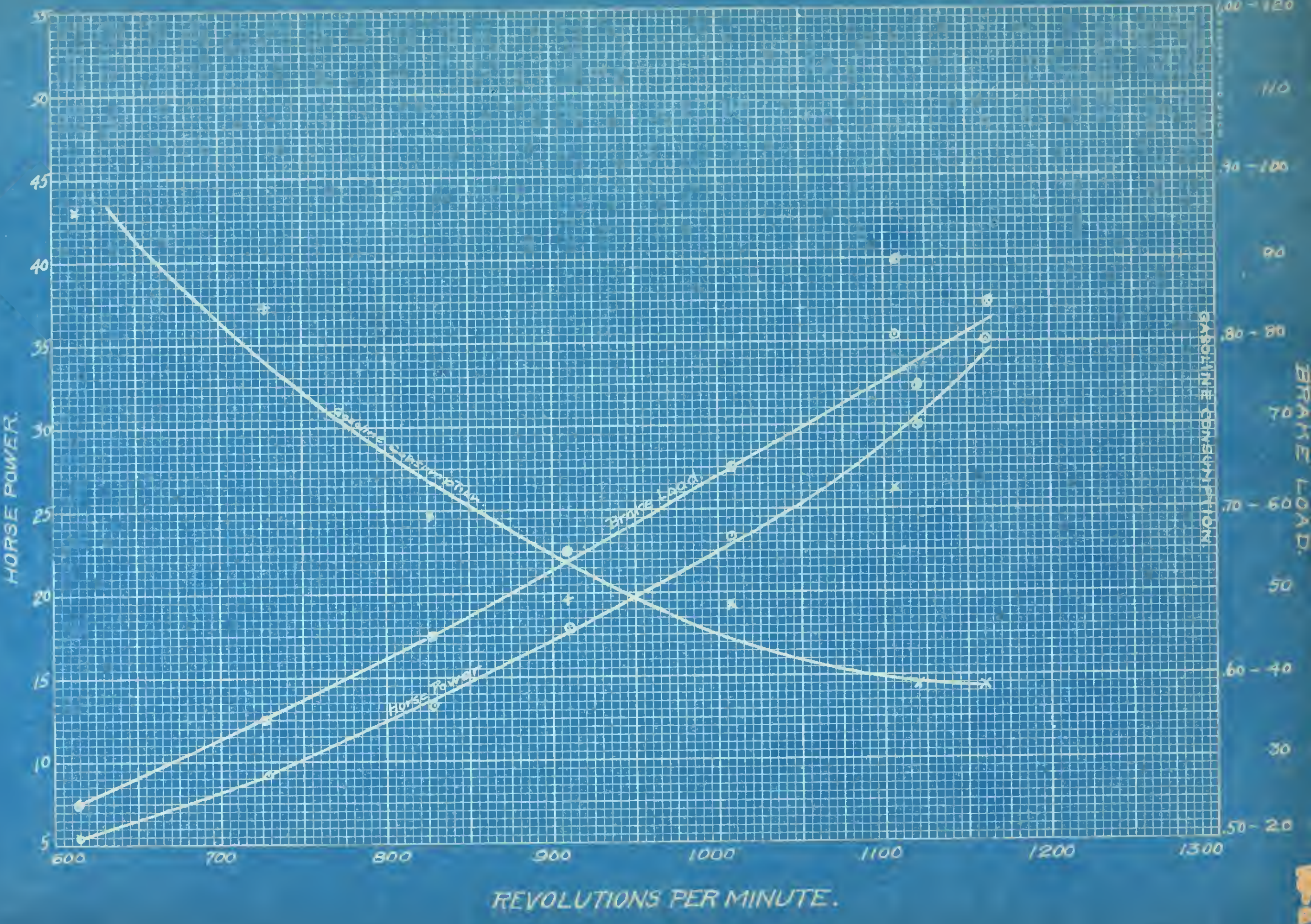
Owing to the fact that difficulties of o operation demanded our continual attention to the load and engine, and since the conditions of this test were so nearly like those in Test Number Seven, we did not attempt to take cards at this load. Cards E-8 and E-9 in all probability will show very nearly the conditions of this run.

The Test Discussed

Owing to the fact that we were trying to get the highest load at this speed, we increased the gasoline consumption to .711 lbs. per B.H.P. per hr. and therefore the test as far as economy is concerned is hot very valuable. The shortness of the test also makes its accuracy, as far as average gasoline consumption rate is concerned, doubtful. Expressed in B.T.U. per B.H.P. per hour, this fuel consumption rate is 13,300 B.T.U. per B.H.P. per hr. against 11080 B.T.U. per B.H.P. per hr. for Test Number Seven, the most efficient run. This

is an increase of 2220 B.T.U. per B.H.P. per hr., or 16.7%. The outlet cooling water temperature was 99.9°F against 87.4° F of Test Number Seven. The percentage of heat given up to cooling water is 34.8% compared with 33.7% for Test Number Seven. This represents an increase of 1.1%. The presentage of heat given up to radiation, exhaust and etc., is 46.04% against 43.38% fro Number Seven. This is an increase of 2.66%.

The thermal efficiency in Test Number Eight is 19.16%, that of Test Number Seven is 22.92%, representing a drop in efficiency of 3.76%.


HORSE POWER.
5
10
15
20
25
30
35
40
45
50
55
REVOLUTIONS PER MINUTE.
600
700
800
900
1000
1100
1200
1300
BRAKE LOAD.
GASOLINE CONSUMPTION.
.50 - 20
30
.60 - 40
50
.70 - 60
70
.80 - 80
90
.90 - 100
110
1.00 - 120
Gasoline Consumption
Brake Load
Horse Power

Discussion of Curves.

The horse power curve shows a graduallyrising line, not quite a straight line, up to the highest speed where as it is still inclined upward, it is seen that this speed is not yet near the critical speed where the horse power curve changes direction. The conditions which have previously been mentioned stopped our curves, it seems, just a little before the critical point was reached. This is probably close around 1600 R.P.M. or 1700 R.P.M.

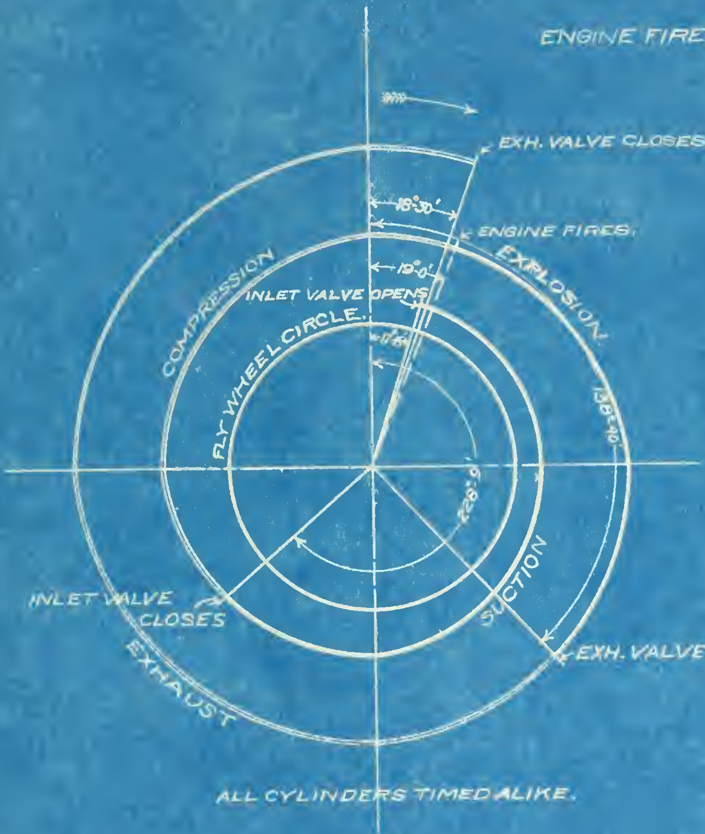
The brake load curve is nearly a straight line, and toward the top shows signs of changing curvature. This would indicate that the curve changes earlier than the brake load curve does. However, this curve is limeted as were the others and one can only guess by indications what they would have been if carried farther.

The gasoline consumption rate curve is the best curve of the three, its downward

slant and gradually curving approach to the end, showing that the lowest point has been reached and from here on the curve would begin to rise.

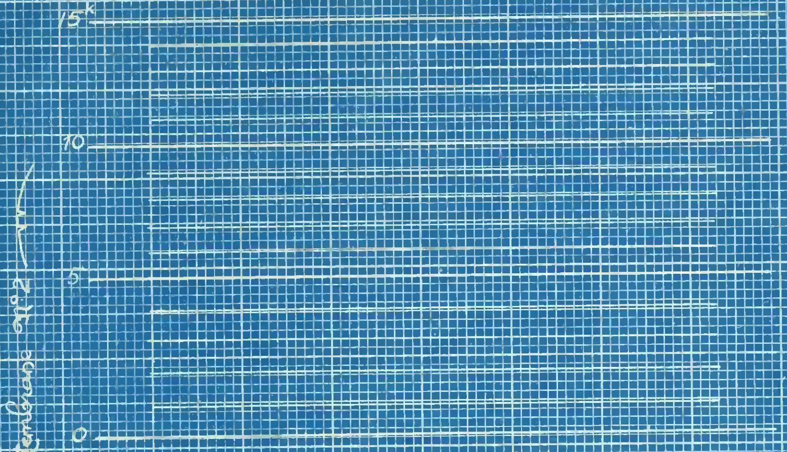
VALVE DIAGRAM.

ENGINE FIRES: 1, 4, 3, 2.



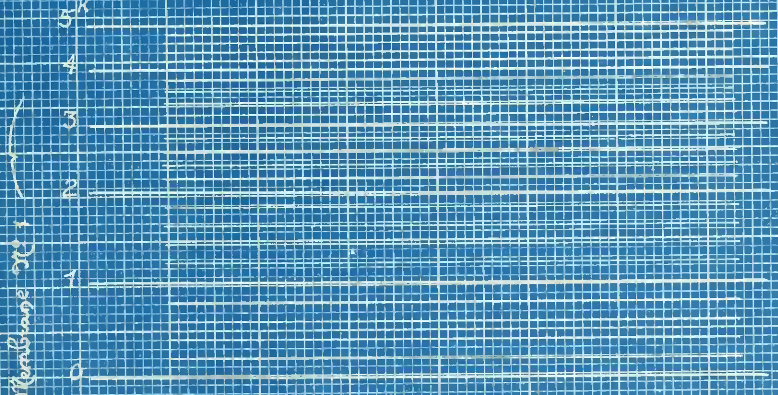
ALL CYLINDERS TIMED ALIKE.

Manographe Hospitalier Carpentier
H 683-7



Echelle des pressions en kilog. par c.m.q
25-1-08

Manographe Hospitalier Carpentier
H 683-7

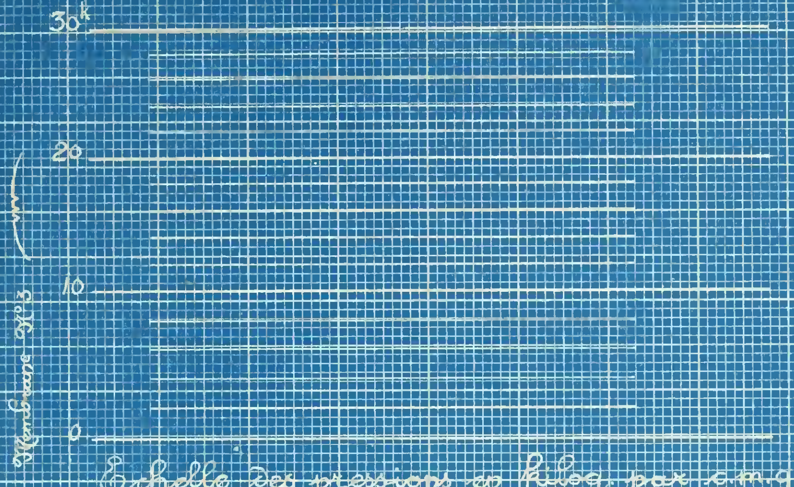


Echelle des pressions en kilog. par c.m.q
25-1-08

H.F. LAWRENCE

Manographe Hospitalier Carpentier

H 683-7

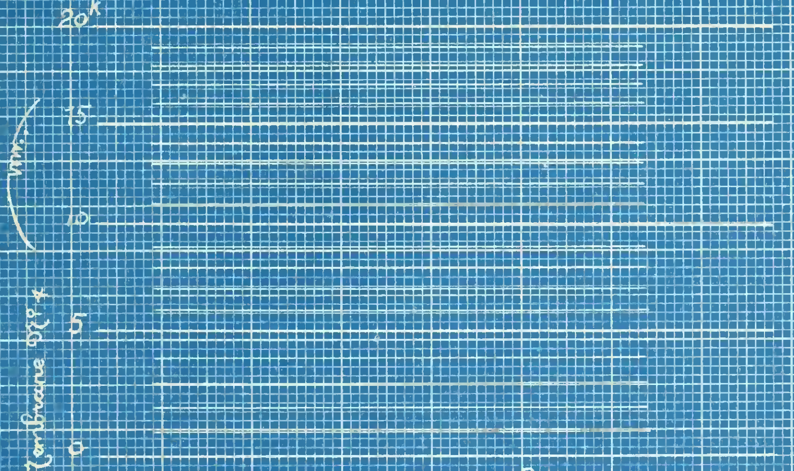


Echelle des pressions en kilog. par c.m.q

25-1-08

Manographe Hospitalier Carpentier

H 200-9



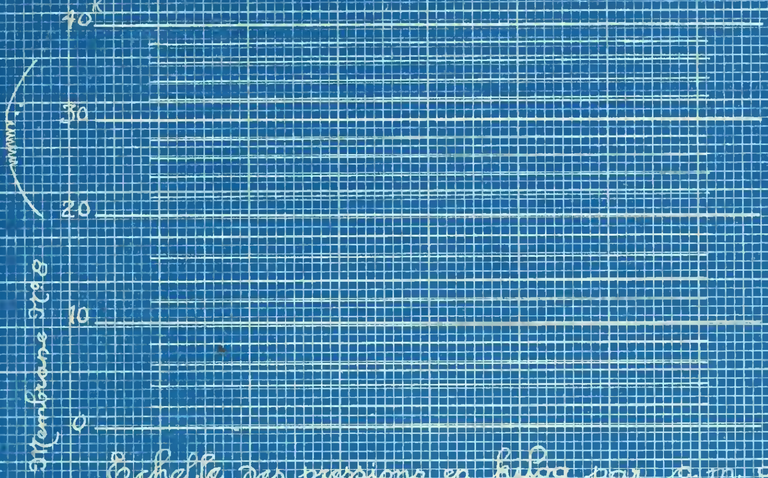
Echelle des pressions en kilog. par c.m.q

25-10-07

N.F. LAWRENCE '12.

Manographe Hospitalier Carpentier

H 200-9



Echelle des pressions en kilog. par c.m. q

25-10-07

H. T. LAWRENCE 12